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Hit Me with your Best Shot: A Critical Analysis of the Resistance to Vaccine Utilization

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HIT ME WITH YOUR BEST SHOT: A CRITICAL ANALYSIS OF THE RESISTANCE TO VACCINE UTILIZATION

by
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DEDICATION

To my parents, who have supported me in all of my personal and academic endeavors. Dad, thank you for sparking my interest in the healthcare field and for encouraging me in my goal of becoming a nurse. I have learned so much from you over the years and seen how your passion to help others pushes you to be the best healthcare professional that you can be. I hope to have that same drive in my career as a nurse and policy leader. Mom, thank you for continually pushing me to not give up and to explore my interests. Without you, I would not have pursued the Public Policy Leadership Degree and would not have found my passion for health policy and healthcare advocacy.

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ABSTRACT
KATHERINE COLEMAN SISTRUNK: Hit Me With Your Best Shot: A Critical Analysis of the Resistance to Vaccine Utilization
(Under the direction of Dr. Joseph "Jody" Holland)

Vaccines have provided humans protection from infectious diseases for centuries, yet the vaccination rate in the United States fails to come near one-hundred percent, allowing vaccine-preventable diseases to re-emerge in communities across the nation. Vaccines have proven to be a safe and effective method in preventing the spread of infectious disease, but vaccine resistance remains high due to false information perpetuated by anti-vaxxers, greatly impacting the vaccination rate in our country. This thesis, by means of a literature review, provides a critical analysis the resistance to vaccine utilization in the United States to determine what policy recommendations and interventions can be made to reduce the resistance to vaccines and increase the vaccination rate in our country.

Vaccine hesitancy has been around ever since the creation of the first vaccine and as the years went on, the modern anti-vaxx movement gained ground, voicing concerns over the ingredients in vaccines, the number of vaccines children receive in their first year, and the belief of the myth that vaccines cause autism. Even after medical science and years of research have validated the safety of vaccines and have shown no link to autism, vaccine hesitancy is still an issue as anti-vaxxers push to receive exemptions for medical, religious or philosophical reasons. Several states offer these types of exemptions, furthering the low vaccination rates in the United States and putting citizens' health and safety at risk.

The findings of the critical analysis was comparable to the literature review: compulsory vaccine laws have proven to be a successful solution to increase vaccination rates; however, these laws are left up to the states, allowing many individuals to go unvaccinated as only Mississippi, West Virginia, and California do not allow religious and philosophical exemptions. In order to address the low vaccination rates in the United States, policy interventions must be made through the states, the federal government, health care providers, and community and government-based organizations to increase the vaccination rate in our country through measures intended to increase vaccine compliance. Without these policy interventions, our nation and our world will never be free from the threat of vaccine-preventable infectious diseases.

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LIST OF ABBREVIATIONS

CDC	Centers for Disease Control and Prevention
GMC	General Medical Council
EMEA	European Medicines Agency
AMA	American Medical Association
WIC	Women, Infants, and Children
WHO	World Health Organization
GBS	Guillain-Barre Syndrome
HIV	Human Immunodeficiency Virus
MMR	Measles, Mumps and Rubella
DTaP	Diphtheria, Tetanus, and Pertussis
IPV	Polio
Hib	*Haemophilus influenzae* type b
HPV	Human Papillomavirus
BCG	Bacille Calmette-Guerin vaccine
PCV	Pneumococcal conjugate vaccine
EMR	Electronic Medical Record

Chapter 1

Introduction

Introduction to Infectious Disease and Vaccination

Infectious diseases have plagued humanity for thousands of years, infecting and killing millions of people in their path. In the seventeenth and eighteenth centuries as sea travel began to blossom, so did the spread of these diseases. Globalization and colonialism brought people together from disparate parts of the world, but also led to the transfer of dozens of deadly pathogens—both bacterial and viral—and contributed to new stresses such as vitamin and protein deficiencies. The New World was particularly hard hit since isolated indigenous peoples had not encountered a host of Old World diseases prior to first contact in 1492, and the conditions of colonialism facilitated the spread of these infectious agents. Before colonial contact with the New World, there were between five and ten million people in North America, and because of the devastation that disease brought along with colonization, by the twentieth century, there were only 237,000 Indians left in the United States (Crosby, 1976).

Morbidity and mortality in our history can be associated with many different factors including problems with sanitation, living conditions, starvation and malnutrition, and poor medical practices, but one thing is for certain: infectious diseases have been responsible for many of our world's deaths over the centuries; however, we have made

significant steps in the right direction. With our world continuing to globalize, the threats that infectious diseases bring continue to linger, but because of the numerous medical and scientific advancements made over the years, we have been able to slow and even eradicate disease.

The first ideas surrounding medicinal thought began with the idea that balancing bodily humors led to good health. Because of this idea, heroic medicine, which was extremely barbaric and often did more harm than good, was introduced to treat disease. Heroic treatments often included methods such as bloodletting, blistering, and using harmful drug concoctions that intended to treat or even cure patients, when really, it more often made the patients sicker. This was extremely primitive medicine, and emerging scientists and physicians in the medical field realized that something different was needed to combat diseases such as smallpox (Dary, 2008).

It is unclear when the practice of "inoculation," or purposefully infecting a patient with smallpox through the scabs or pus from another person infected with the disease to gain immunity, was first practiced. However, evidence suggests that the Chinese practiced the method over one thousand years ago and then the method spread to the rest of the western hemisphere and the Americas by the mid-eighteenth century. Because people realized that those who survived smallpox could never contract the disease again, inoculating people with the disease in turn made the resulting smallpox infection less harmful to the patient than naturally getting the disease, while also providing the patient lifetime immunity. There were some criticisms to this method, however. Some people complained that it interfered with God's plan and that it was a dangerous method. But, it

was proven to be a successful solution, and was used by many medical professionals and even commoners at the time to combat the smallpox infection (Reidman, 1960).

As the practice of inoculation was gaining recognition worldwide, a scientist named Edward Jenner, who was subjected to a cruel inoculation practice in England as a child, was determined to find a safer and more effective method. Jenner noted that milkmaids rarely got smallpox and discovered it was because of their exposure to cows with cowpox. So, because of this discovery, the first smallpox vaccine was developed in 1796 with the slightly safer method of using the pus from a cow with cowpox for inoculation rather than the full-blown smallpox virus. This new theory by Jenner was tested on an eight-year-old boy and was successful. When the boy later came into contact with smallpox after being inoculated with cowpox, he did not become infected with the smallpox virus, showing that the vaccine that Jenner developed had worked and made people resistant to smallpox (Link, 2005).

Jenner's research and experiments with cowpox led the way for the development of the first vaccination, and today, smallpox has been eradicated worldwide, representing a major milestone in the control of infectious diseases and further proving that through drastic public health and vaccination measures, disease can be conquered. (Greenwood, 2014). Vaccines have allowed us to gain protection against diseases that have infected millions of people worldwide, including measles, mumps and rubella (MMR), pertussis, yellow fever, and tuberculosis. Because of this medical advancement, we are now able to protect ourselves from a multitude of preventable diseases that our world may still be suffering from without the formation of vaccines (Feemster, 2018).

Introduction to Vaccine Resistance

There are many reasons, some being religious or philosophical, why parents specifically do not want to vaccinate their children, and many states offer exemptions to allow parents to do so. A majority of states allow exemptions to vaccines for both religious and medical reasons, but many states also allow exemptions for philosophical reasons as well. What is most interesting is that the states that are well behind most in health outcomes in our country are the ones that have the strictest vaccination laws: Mississippi and West Virginia. California also recently changed their laws to mimic those of Mississippi and West Virginia after a measles outbreak in Disneyland sickened dozens of children in 2015 (National Vaccine Information Center, 2018).

Despite laws that mandate vaccination, there are still people in our world, mainly children, who are suffering from vaccine-preventable diseases. If we continue to ignore this problem, the health of our nation could be compromised as outbreaks of infectious diseases become too large to control. In fact, an estimated twenty-three million infants did not receive routinely recommended vaccinations in 2012 (Bårnighausen, Bloom, Cafiero-Fonseca & O'Brien, 2014). Additionally, the World Health Organization (WHO) estimated that measles cases spiked thirty percent worldwide in 2017 due to poor vaccination rates, and out of the 6.7 million people who got measles in 2017, 110,000 died from the virus (Fox, 2018). In the 1970s, many medical experts thought that the fight against infectious diseases was over, and the Surgeon General at the time even said that it was "time to close the book on infectious diseases, declare the war against pestilence won, and shift national resources to such chronic problems as cancer and heart disease" (World Health Organization, 2018). Because of the increasing number of people refusing

vaccination over the last few decades, the progress that our world has made in eliminating infectious diseases is quickly being reversed.

With our ever-globalizing planet, infection control has become increasingly important. Our world is always subject to new outbreaks of infectious disease, as we have seen in Africa in 2012 with the Ebola virus epidemic that affected several African countries including Sierra Leone, Liberia, and Guinea. This outbreak not only highlighted our global vulnerability to disease, but also caused mass hysteria around the globe with the fear that the virus would spread to places such as the United States. The virus was mostly contained in Africa, but cases still persist in the continent even today, showing the resilience and dangers of infectious disease (Looke, Gottlieb & Jones, 2015).

In addition, as mentioned previously, the 2015 measles outbreak in Disneyland sent a message to many Californians on the importance of vaccination. Of the 110 Californian patients infected with measles from their trip to Disneyland, 49 were unvaccinated; and of the 49, 12 were too young to receive vaccinations and the remaining 37 had refused vaccination for personal beliefs. Because of one person's exposure to measles, hundreds of people became infected and many who were sick were too young to even get vaccinated, prompting the California legislature to reconsider their vaccination laws. Today, California, along with Mississippi and West Virginia, have the strongest compulsory vaccination laws in the nation (Zipprich, Winter, Hacker, Xia, Watt & Harriman, 2015).

Magnitude of the Problem

The magnitude of this problem is large, not only in the United States, but around the world, prompting the need for a solution to this public health problem. Whether it be through vaccine and public health education, increased compulsory vaccine laws, or other policy interventions, citizens in the United States need to be educated surrounding the facts of vaccination in order to be informed citizens who can make smart decisions in regard to their health and the health of those around them. Today, more than eighty-five percent of children worldwide are vaccinated annually against diseases such as diphtheria, tetanus, pertussis, tuberculosis, polio, measles, and hepatitis B, preventing an estimated 2.5 million deaths each year (Children's Hospital of Philadelphia, 2018). People across the nation need to understand that vaccination is key to protecting the health and safety of our country and informing and educating the public on the importance of vaccination, coupled with compulsory vaccination laws and other policy interventions, is the solution.

Purpose of Study

The driving question surrounding this thesis is, why do people resist vaccination and what policies and interventions can be introduced to mitigate this resistance? In order to answer this question, the author must fully understand the evolution of vaccination and the scope and evolution of the resistance to vaccination, which will be discussed in later chapters. The intent of this thesis is to critically analyze the evolution of vaccination and the evolution of resistance to vaccine utilization in the United States to determine what policy recommendations and interventions can be made to reduce the resistance to vaccines and increase the vaccination rate on our country.

In this thesis, the author will first outline the methodology for the research, which consists of a literature review. Next, in chapter 3, the author will give a historical background of vaccines and the effect of infectious diseases on humanity before outlining the evolution of vaccination. In chapter four, the author will provide the findings of the research through outlining the evolution of vaccination. Finally, the author will present final recommendations through policy interventions to attempt to solve the problems surrounding resistance to vaccine utilization.

Chapter 2

Methodology

Using a literature review, the author developed a deeper understanding of vaccination as well as critically analyzed the resistance to vaccine utilization in the United States to determine what policy recommendations and interventions can be made to reduce the resistance to vaccines and increase the vaccination rates in our country. The author performed this review by means of computer search using the University of Mississippi Libraries OneSearch. The resources selected for this research analysis focused on the following: the effect of infectious diseases on humanity, history of vaccines, the evolution of germ theory, types of vaccines, components of vaccines, vaccination disasters, vaccinations for the future, the current state of vaccination, the history of vaccine resistance, the current anti-vaxx movement and vaccine controversy, policy recommendations to combat anti-vaxxers, and educational programs for the promotion of vaccine efforts.

This research provides a particular emphasis on the evolution of vaccines and the evolution of vaccine resistance in order for the author to develop a deeper understanding of the subject. The literature review research design aids the author in their efforts because there are thousands of sources pertaining to vaccines that have been published both online and in print. This research includes analysis of the resistance to vaccines as well as the impact that the resistance has had on humanity. By utilizing a literature

review, the author aims to provide a comprehensive examination of vaccines and vaccine resistance by compiling these different areas of research into a comprehensive analysis so that a policy recommendation can be made.

The data collected ranged from scholarly peer-reviewed articles to published books, court cases, various websites, and quantitative and qualitative vaccination data. The approach to reviewing the available peer-reviewed journal articles is as follows: (1) advanced search vaccination in the University of Mississippi Libraries One Search using indicator words, (2) filtered responses for peer-reviewed and full article available online in the order of most relevant, (3) reviewed titles, descriptions, and article abstracts for content related to the author's research, and (4) selected articles with varying content that together aid to help the author in their analysis of vaccines and vaccine resistance and also help them to find other useful print and online sources in order to accurately understand vaccines and vaccination resistance to make a policy recommendation.

The indicator words and phrases used in One Search included *vaccination, vaccine, inoculation, vaccine history, vaccine resistance, vaccine schedule, anti-vaxx movement, vaccine education, current state of vaccination.* This process produced a total of 51,633 results. Then, the results were narrowed by redefining the search to include full text online and peer-reviewed sources, giving 5,797 results. Then, the results were narrowed even further by defining results limited to journal articles in English published in the past year whose subject matter related to vaccines, vaccination, immunization, infectious diseases, medicine, United States, humans, epidemiology, public health, prevention, disease, vaccine, inoculation, disease control, epidemics, biology, smallpox, vaccination and immunization, which resulted in 200 sources. These sources were then

evaluated for their relevance to the author's research by conducting an analysis of titles, descriptions and abstracts. The articles that were determined to be beneficial to the author's research were then saved to a computer folder for analysis. The sources that were saved to a computer folder were then categorized into themes such as history, current state, pro-vaccination, anti-vaccination, vaccine resistance, and vaccine data. These themes appeared organically as the author collected and evaluated the research.

When evaluating the sources that were produced from the University of Mississippi Libraries OneSearch, several books, websites, and other journal articles were mentioned in the research, allowing my research to expand further with the introduction of these other sources. Additionally, when reviewing these OneSearch sources, the author was inspired to search for further sources in the forms of books, websites and other journals to aid in the analysis, so several other sources were introduced into the research. Current events were also taken into consideration within the research as outbreaks of disease have been common in the United States in 2019.

This detailed analysis aided the author in answering the proposed research question. By focusing on the indicator words listed and breaking down the research into smaller subsection, the author was able to outline and organize the research, findings, and recommendations to present a comprehensive analysis of vaccines, vaccine resistance, and how to mitigate vaccine resistance. By using a literature review as the methodology for this research, the author was able to gather research and data in order to recommend policies that aim to decrease vaccine resistance and increase vaccination rates.

Chapter 3

Background

Evolution of Vaccination

For centuries, man has attempted to prevent disease through whatever means necessary, formulating theories and methods on how to best prevent or treat disease. The first recorded description of disease, according to Cyril William Dixon in his text on smallpox, was in 1160 B.C. with the Egyptians. It is believed, through his mummified remains, that Ramses V, Pharaoh of Egypt, had died from smallpox (Fulginiti, 1982). This ancient disease was scouring the globe, and people began trying various methods in devising a solution. The first conceptual knowledge of vaccination occurred in ancient Greece, when physicians first started to understand that getting infected with smallpox could prevent later infections of the same disease. In fact, in 429 B.C., Greek historian Thucydides recorded the observation that people who survived smallpox in Athens, Greece were safe from re-infection (Bushak, 2016).

It was not until one-thousand years ago when the Chinese began their method of "variolation" that a solution to this dreadful disease was first observed. Variolation, or deliberately infecting a person with disease to cause a milder case and protect the individual from contracting the natural, more severe form of the disease, was used as a solution to smallpox at that time (Link, 2005). Historians debate on when this method was first seen in China, but most agree that it was about one-thousand years ago. Vincent

Fulginiti (1982) writes that the Chinese first utilized variolation as early as 590 B.C. by implanting bamboo splinters containing infected pustular material into the nasal passages of uninfected individuals. However, the agreement seems to be that this method was first introduced around 900-1000 A.D., and that the most common method was taking dried crusts or scabs from a smallpox patient, grinding them up, then placing the powder in the nose where the patient then inhaled it, triggering a less severe form of the smallpox virus along with lifetime immunity (Feemster, 2018). Through this method, the Chinese discovered that they could store the smallpox crusts from infected patients in sealed vessels for months, and the matter would still work and retain its potency when used on other patients months later. This method created by the Chinese, along with other similar interventions, were used for hundreds of years in Asia, the Middle East, and Africa until the idea finally spread to Europe in the eighteenth century (Reidman, 1960).

In the early eighteenth century, the practice of inoculation was largely confined to the eastern countries of China, India and Turkey until Lady Mary Wortley Montague, wife of the British Ambassador to Turkey, learned of "smallpox parties" during her time in Turkey. She was disfigured from suffering from the disease herself in 1715 and was determined to find a solution to protect her family (Bushak, 2016). In 1717, during the reign of George I, she wrote to a friend in England, saying

> I am going to tell you a thing that I am sure will make you wish yourself here. The smallpox, so fatal and general among us, here is entirely harmless by the invention of engrafting (variolation). There is a set of old women who make it their business to perform the operation every autumn in the month of September when the great heat is abated… They make parties for the purpose… the old

> woman comes with a nutshell full of the matter of the best sort of smallpox, and asked what veins would you please have opened. She immediately rips open… and puts into the vein as much matter as can lie upon the head of her needle. (Link, 2005, p. 11-12).

Lady Montague was so enthusiastic about the procedure that she brought the practice to Britain, where she had her five-year-old son inoculated. Within a few days, she wrote to her husband that the boy was singing and playing and could not wait until supper was ready. In the years after, Lady Montague spread the practice throughout England, decreasing the number of smallpox cases dramatically (Reidman, 1960; Link, 2005). She has been credited as being the first to bring attention to the practice of inoculation in England, and eventually to the Western world (Bushak, 2016).

Some were still skeptical about this practice, including King George I. So, the King directed the embassy physician in Constantinople who witnessed the variolation of the Montague household to try the practice on seven criminals who were sentenced to death. The criminals survived inoculation and earned pardons, rendering the practice safe to the King, causing it to further spread throughout England and beyond. In fact, because of Lady Montague, Frederick the Great and the Crown prince of Denmark were inoculated by Dr. Thomas Dimsdale of London, and Empress Catherine of Russia invited Dr. Dimsdale to spread the practice in Russia. The popularity of this method had spread throughout Europe and Asia, and even to the Middle East, where Arabs had a custom called “buying the smallpox,” where they would squeeze pus from an infected child and introduce it to the skin of another person, paying the smallpox “donor” with raisins, dates, or candy (Reidman, 1960).

In England, “Inoculation Houses” were formed by the apothecary Robert Sutton, where it became a business to inoculate patients and take care of them throughout the duration of the resulting illness. Sutton’s method was different than most in that he took precautions in preparing the patient and providing care afterward. He would prescribe a period of rest and proper diet before inoculation and during the procedure, he used a small amount of matter from an infected blister instead of from a crust, inserting it into the skin in the upper arm and avoiding the use of bandages after the fact (Reidman, 1960). Additionally, after learning from a technique practiced in South Carolina in 1738, the Suttons acquired infectious matter from another inoculated patient, not from a victim of natural smallpox, making the resulting infection less severe. After inoculation, the patient was then quarantined from the community at large in a room that allowed the patients to have adequate air flow, allowing them to heal while protecting the community (Fenn, 2001).

This safer method became widely popular; however, it was not always done in the same safe way that Sutton introduced. Among the elite in England, this practice developed into a costly and elaborate procedure in which patients were subjected to blood-letting, purging, starving and purifying in inoculation houses before variolation, then confined to the buildings until the illness subsided. Edward Jenner, the man who invented the first smallpox vaccination in the late eighteenth century, was even subjected to this method as a child (Link, 2005).

As different methods of smallpox inoculation were spreading throughout the eastern hemisphere, it was finally introduced in America in 1721 by Zabdiel Boylston, a Boston doctor. He successfully inoculated his young son and his two servants; however,

there was more setback. After his success in inoculation led others to try the procedure, one person died as a result, causing many to refer to the practice of inoculation as the work of the devil that defied the will of God. However, many still believed in the method including Benjamin Franklin, who worked with Dr. William Heberden of London in writing a booklet on smallpox inoculation. Franklin advocated for those who could not afford the often-expensive inoculation practice, teaching in his booklet how to do the procedure in hopes that parents would inoculate their children. In the pamphlet, Dr. Heberden and Benjamin Franklin provided simple instructions that could be easily followed, allowing people to understand how to do the practice on themselves and their families that could not afford the procedure otherwise (Reidman, 1960).

In the following decades during the late eighteenth century, American medical students traveled to England and Scotland to learn the safe Suttonian Method of inoculation, bringing it back to America. Among these students was Dr. Benjamin Rush, who promoted smallpox inoculation in Philadelphia and ultimately introduced the method to George Washington's Continental Army, saving many lives that would have been lost to disease during the Revolutionary War (Reidman, 1960). However, the popularity of inoculation began to diminish as the years went on due to the often-unsafe methods used, coupled with the fact that the practice kept the disease alive and thriving in society, for people not inoculated were always exposed to those who had it in the mild form. Additionally, there were occasional deaths from the inoculation method, and many argued that it interfered with God's plan. In fact, a law was passed in 1762 in France that prohibited the method entirely (Reidman, 1960).

In addition, the practice became extremely controversial in the Americas and began to be restricted. After the Williamsburg smallpox outbreak in 1768, the Virginia Legislature received numerous petitions to stop the practice of inoculation in Virginia. While inoculation was not banned entirely in response to this, the regulations imposed in 1770 were so restrictive to the practice that they essentially had the same effect as a ban. In Charleston, South Carolina, the first inoculation law was in 1738. It was an ordinance that imposed a large fine on anyone giving or receiving inoculation within two miles of the city. New York passed a similar law in 1747, further restricting the practice (Fenn, 2001).

Inoculation became a widely restricted and unpopular practice in New England, while it remained a popular practice among many across the ocean in the Eastern hemisphere. However, some colonies still allowed the practice, and it flourished in Maryland, New Jersey and Connecticut. The practice was again becoming hard to find and expensive for many people due to these restrictions, and often those who could afford it, the affluent Americans, fought for the practice, while those who could not afford the procedure, fought against it. The practice became more accessible in the years leading up to the Revolutionary War, and more people were inoculated as more outbreaks of smallpox occurred (Fenn 2001). It was clear that a new and safer solution was needed to combat and ultimately eradicate smallpox, and English scientist named Edward Jenner answered the call.

Edward Jenner and the Smallpox Vaccine

Edward Jenner was born in Berkeley, Gloucestershire, a farming town, in 1749. Young Edward began his medical journey through an apprenticeship to Mr. Daniel Ludlow where he learned the practical art of medicine and surgery, while also learning to observe and care for the sick. Jenner continued to learn from more and more medical professionals over the years and took in everything he could about medicine and the body. He was passionate about learning, and never stopped exposing himself to new things, always looking for something new to discover. This began his long career in the medical practice and ultimately led to his creation of the first vaccine (Reidman, 1960).

Jenner grew up in a farming community, dairy farming in particular, where he constantly noticed and observed the contagious disease of cattle that the farmers referred to as "cowpox." This infection affected the cow's udders where red pimples erupted over the surface, later becoming watery blisters that formed a scab, leaving behind a pitted scar (Reidman, 1960). Cowpox, named after its similarities to smallpox, was not as severe as smallpox, but along with the pustules and fever, it also caused aching joints and limb pain in humans. However, the biggest difference between the two was that cowpox did not cause disfigurement or death (Feemster, 2018). This disease among cattle was medically-termed "Vaccinia," and it was spread from cow to cow by the milker's hands. Herds of cows would become infected and sometimes it would be passed to the milkmaids or dairymen, resulting in a sickness that caused a slight fever and pimples on the hands that blistered, scabbed, and scarred just as the cowpox affected the cattle (Reidman, 1960).

Jenner noticed that most faces in his city bore scars of smallpox, while the faces of milkmaids and dairymen were unblemished. He theorized that the frequent occurrence of cowpox and its association with the daily work on a dairy farm somehow protected the milkmaids and dairymen from smallpox (Link, 2005). He even recorded a similar theory during his apprenticeship with Mr. Ludlow when a young girl came in during a smallpox outbreak in the community, boasting how she was not afraid of catching the disease because she had previously been infected with cowpox as a child (Reidman, 1960).

Jenner decided to test his theory with an experiment. On May 14th, 1796, he obtained a sample of pus from a cowpox ulcer on the hand of Sarah Nelmes, a milkmaid, and administered the sample to a young boy by the name James Phipps. A few weeks later on July 1st, Jenner inoculated Phipps with smallpox and waited for the result. The conclusion was remarkable: James Phipps was immune to smallpox. Jenner termed this new procedure "vaccination" after the Latin word for cow, and by 1801, one-hundred thousand people throughout Europe had been vaccinated with the first cowpox-based smallpox vaccine (Link, 2005; Feemster, 2018). Vaccination was the updated word for this new method of inoculation created by Jenner as it differentiated between injection with cowpox matter rather than inoculation with smallpox matter. Today, these two terms "vaccination" and "inoculation" are often used interchangeably, but in Jenner's time, vaccination distinguished his method from the older method of inoculation (Reidman, 1960).

Even after Jenner's remarkable breakthrough, some doctors and scientists were still skeptical about the method. Jenner presented his discovery to the Royal Society in 1796, but his paper was refused. He was told to investigate further and publish his result

in a book, so for the next two years, Jenner collected more evidence and was finally ready to present his work again. He traveled to London to share his discovery with many skeptics about his methods but again was met with criticisms about the safety of his method and was unable to find a patient to demonstrate his work. So, Jenner once again returned home to try to gather more evidence, but he left a small amount of smallpox matter and a vaccination with a surgeon named Henry Cline as well as leaving his manuscript with a London printer in hopes that they would possibly believe in his methods. His hope came true when Dr. Cline tested Jenner's matter on a child, and Cline wrote to Jenner, saying

> The cowpox experiment has succeeded admirably… Dr. Lister, who was formerly a physician to the Smallpox Hospital, attended the child with me, and he is convinced that it is not possible to give him the smallpox. I think the substituting of cowpox poison for the smallpox promises to be one of the greatest improvements that has ever been made in medicine; for it is not only safe in itself, but also does not endanger others by contagion… (Reidman, 1960, p. 35).

Jenner's seventy-five-page manuscript, *An inquiry into the Causes and Effects of the Variolae Vaccine, a Disease Discovered in some of the western counties of England, particularly in Gloucestershire, and known by the name of Cowpox*, was printed and distributed worldwide. Finally, the world knew that those who had cowpox were immune to smallpox, cowpox could be transmitted by vaccination, and it gave the same protection as the disease itself (Reidman, 1960). Jenner's theory was finally gaining acceptance in the world of medicine, and his discovery has led the battle of infectious disease ever since.

Evolution of Germ Theory

Even though Edward Jenner did not necessarily know the science behind his discovery, he still found a way to protect people against smallpox. It was not until the mid-nineteenth century that microorganisms, or germs, that caused infectious diseases like smallpox were understood. Microorganisms were first observed under a microscope by Robert Hooke and Antoni van Leeuwenhoek in the mid-seventeenth century (Gest, 2004). However, it was not until two centuries later with English physician, John Snow, that the connection between germs and disease was discovered. Modern epidemiology was born in 1854 when Snow determined that the source of the Cholera epidemic in London was due to water that was contaminated in the city's pump. After he ordered the pump closed, the epidemic ended, showing his observation was correct. Was this a coincidence or a major scientific discovery? Many physicians at the time refused to believe that invisible microorganisms could spread and cause disease. However, research later done by Louis Pasteur and Robert Koch solidified Snow's argument (Kusinitz, n.d.).

Louis Pasteur was born on December 27th, 1822, in Dole, France and at a young age became interested in research. Pasteur began his first major studies with fermentation when he was appointed to a lab in Lille in 1854. Pasteur believed that fermentation was carried out by living microorganisms but had to prove his theory to other scientists who believed that it was caused by spontaneous generation. Through his experiments, he discovered that fermentation was caused by microorganisms and that they could be helpful in this way, and he eventually learned through his observations on fermentation that spoilable foods could be preserved, or "pasteurized." He realized that the reason that food spoiled was because of unwanted microorganisms in foods and that the

microorganisms could be destroyed by heating and proper sealing, allowing the substance to be stored for long periods of time without spoiling. This practice was coined "pasteurization" and is technique used to this day (Science History Institute, 2017).

Through his research with microbes, Pasteur proved that microbes could not come out of nothing, disproving the idea of spontaneous generation that had long been believed by many scientists, and he was sure that microbes must also cause disease, promoting his studies of germs and their relation to disease (Reidman, 1960). He observed that, "There are similarities between the diseases of animals or man and the diseases of beer and wine" (Kusinitz, n.d.). The idea of spontaneous generation also received a blow in 1858 when Rudolf Virchow, a German scientist, introduced the concept of biogenesis, the idea that living cells can only arise from other preexisting cells. Germ Theory was finally taking shape, and scientists were beginning to understand that microorganisms can invade the body and cause certain diseases. However, it was not until 1876 that German physician Robert Koch proved that bacteria can cause disease, confirming the validity of Germ Theory once and for all (Kusinitz, n.d.).

Robert Koch was born in 1843 in northern Germany. A miner's son, he was one of thirteen children and studied to become a doctor at the University of Gottingen. He studied under Berlin anatomist, Jacob Henle, who worked out the theory that infectious diseases were carried out by invisible forms of life. Koch was eager to learn and with the help of his wife, got his first microscope and got to work. He observed the deadly disease anthrax that was plaguing Germany, not only killing sheep, but also killing the farmers, wool sorters, and hide dealers that dealt with the sheep. No one could explain why healthy sheep suddenly died within a day, and Koch decided he would investigate. Using

his microscope, he examined a drop of blood from a dead sheep, and among the usual components of blood, he also saw small, short rod-shaped structures within the liquid. He decided to test the blood of a healthy animal to see if they contained these same rods, and to his amazement, they did not (Reidman, 1960).

He set up a laboratory in his office and set out to study these rods that he had found. He began infecting mice with the anthrax-infected blood from the sheep and discovered that he was able to transfer the deadly disease to mice, as they lay dead in their cages the day after inoculation. He examined the mice blood under his microscope and once again observed the tiny rod-shaped structures that he saw in the anthrax-infected sheep's blood. He transferred the infected blood from the dead mouse to another mouse and did this over and over all ending with the same conclusion: many dead mice with the same rod-shaped structures found in their blood (Reidman, 1960).

He then set out to prove what he observed by attempting to grow the structures outside of the mouse's body. He theorized that he would have to create an incubator as he knew that an animal's warm body was able to grow the structures, so he created a makeshift one with an oil lamp. He added a tiny scraping of an infected mouse spleen to the incubator and waited for the rod structures to multiply. Amazingly, his incubator worked, and the tiny rods began to multiply. He did this same procedure over and over until he ran out of infected mouse spleen. Then, he began to wonder if this lab-grown matter could kill a mouse or sheep if it were injected into them. This was his next question to answer. Koch transferred the lab-grown matter into a healthy mouse and the next morning awoke to another dead mouse. He examined the spleen and again saw the tiny rod-shaped structures, proof that tiny microbes caused disease (Reidman, 1960).

This experiment allowed Koch to prove that one kind of bacillus was the cause of one particular disease, and in this case, he showed that the bacterium *Bacillus anthracis* was the cause of anthrax in animals. This experiment allowed Koch to come up with specific guidelines for determining the cause of infectious diseases, now known as Koch's Postulates. His postulates are:

1. The organism must be present in every case of the disease.
2. The organism must be isolated from a host with the corresponding disease and grown in pure culture.
3. Samples of the organism removed from the pure culture must cause the corresponding disease when inoculated into a healthy, susceptible laboratory animal.
4. The organism must be isolated from the inoculated animal and identified as being identical to the original organisms isolated from the initial, diseased host.

These postulates are followed by every researcher that attempts to obtain proof that a particular organism causes a particular disease. By showing how specific organisms can be identified as the cause of specific diseases, Koch disproved the theory of spontaneous generation while finally proving the validity of Germ Theory, which was a major milestone in the world of science and medicine. Along with other scientists like Hooke, van Leeuwenhoek, and Pasteur, Koch laid the foundations of microbiology and allowed the creation of even more medical advancements, including vaccinations, that have impacted our world's health (Kusinitz, n.d.).

Koch's postulates began the Golden Era of medicine, allowing microbiologists to isolate the microbes that caused cholera, typhoid fever, diphtheria, pneumonia, tetanus, meningitis and gonorrhea between 1879 and 1889 and later allowing scientists to create vaccines for several of these diseases. Additionally, Koch's work influenced Joseph Lister, a surgeon who wanted to find a way to prevent infection in the operating room. By using phenol to prevent infection, Lister was one of the first to use his knowledge of Germ Theory to control infectious diseases. After his methods of infection control became known, public health measures were created in communities to increase hygiene and reduce contamination through keeping communities clean and utilizing vaccinations (Kusinitz, n.d.). Germ Theory was revolutionary and allowed the creation of more and more vaccines and public health measures up through the twentieth century until a new hurdle was reached: the battle against polio.

A New Fear: Polio

The start of the twentieth century brought many successes in the battle against infectious diseases but also brought new fears thanks to a disease that frightened young and old alike: poliomyelitis. Poliomyelitis, often just shortened to polio, comes from the Greek words for grey and marrow, referring to the spinal cord, and the suffix -itis, meaning inflammation. The disease caused paralysis and was mostly seen in children, which led it to be called infantile paralysis, but it did not only affect the young, it affected everyone. The virus was spread through contact between people by nasal and oral secretions, and also through contact with contaminated feces. In about 98% of cases, polio is only a mild illness with no symptoms. However, in the other 2%, paralytic polio can develop, attacking nerve cells and causing paralysis that often leads to death if

artificial breathing support is not used (The College of Physicians of Philadelphia, 2019). Even though this disease did not affect people on epidemic proportions as smallpox once did, the crippling paralysis it caused ensued fear among many, and the iron lung became a symbol of the fear that this disease brought in the twentieth century.

Polio was by no means a new disease in the twentieth century. It was first seen over three-thousand years ago in ancient Egypt through a drawing on a stone slab of a young boy leaning on a crutch with his muscles shrunken and limbs useless. However, unlike other infectious diseases that spread rapidly and caused large epidemics, polio is harder to spread, which allowed it to slip through the cracks from century to century until re-emerging as a force to be reckoned with in the twentieth century. The first to recognize polio as a distinct disease was Dr. Michael Underwood, a British physician, in 1784. It was not until over one-hundred years later that it was discovered that polio was caused by an infectious agent. The first case to occur in the United States was in 1894 in Vermont, when a child began to show symptoms of polio including nausea, high fever, headache, stiff neck, and later paralysis. After this case, more and more children became sick as outbreaks began spreading throughout the United States (Reidman, 1960).

For the first time in its history, polio reached epidemic proportions in the early 1900s at a time when other diseases such as diphtheria, typhoid, and tuberculosis were declining due to vaccination. Strangely enough, the disease spread with great virulence into parts of the world where sanitation and infection control were good while epidemics in the more primitive parts of the globe were unheard of. Many scientists think that this was because as hygiene practices were becoming more advanced, fewer people were becoming exposed to polio as infants through practices such as breastfeeding, which did

not allow them to form antibodies that protected against the disease in their blood. So, because better sanitary conditions meant that exposure to polio was delayed until later in life, children became more vulnerable to the disease (Reidman, 1960; The College of Physicians of Philadelphia, 2019).

As ironic as this phenomenon was, polio was threatening young and old alike, and a solution was needed in order to stop this terrifying disease. In 1921, Franklin Delano Roosevelt was infected with polio and became paralyzed from the waist down. He turned his unfortunate situation into a positive outcome, using his experience with the disease to inspire courage among millions of people. Up until he was elected President, Roosevelt fought for those with polio and created a foundation to fundraise for a cure. The March of Dimes, a fundraiser for the cure of polio, was an event celebrated on Roosevelt's birthday and raised over a million dollars in its first year in 1934. Four years later, the National Foundation for Infantile Paralysis was founded in order to further research the polio virus in order to find a cure (Reidman, 1960).

Unlike diseases such as diphtheria and anthrax that infect the blood and that scientists were able to create a vaccine for using the knowledge of Germ Theory, polio is caused by a virus that attacks nerve cells, which is another beast of its own. Viruses are more difficult to combat than bacterial infections, and because polio lives inside nerve cells, it was hard to study. In 1949, researchers at Harvard found a way to grow the polio virus in a test tube, which allowed for more effective research without the use of polio-infected monkeys to ensue. Also, their discovery allowed scientists to realize that the disease was spread through the mouth where it would eventually affect the nerves, earning them a Nobel Prize (Riedman, 1960).

The start of the polio vaccine trials began in 1935 with Dr. Maurice Brodie and Dr. John Kolmer, and both trials came to disastrous ends. Dr. Brodie researched at New York University and developed a killed polio vaccine and tested it on chimpanzees, himself, and children. He enrolled about eleven-thousand individuals in his trial. Similarly, Dr. Kolmer of Temple University developed an attenuated polio vaccine and tested it in about 10,000 children. Both trials ended poorly as several children died of polio and many others were left paralyzed or ill from the vaccinations (The College of Physicians of Philadelphia, 2019).

After the failure from the 1935 trials, scientists were determined to find a cure but were met with controversy from the public as more vaccines were being developed due to the harsh and deadly consequences that they had brought in the past. In 1950, Dr. Hilary Koprowski of Poland conducted the first human trial of his oral polio vaccine on twenty children, and his experiment demonstrated that none of them became ill with polio, and they all developed polio antibodies. What was most astonishing is that Dr. Koprowski had tested his vaccine two years earlier, but on himself. At this time Koprowski's methods generated considerable controversy among others who were working on vaccines, as they believed that testing on human subjects was dangerous as the 1935 trial demonstrated (The College of Physicians of Philadelphia, 2019). However, his method worked, which was a huge step in the battle against polio.

Dr. Koprowski's cure for polio is far less well-known than later scientists such as Salk and Sabin's methods because it was never approved for use in the United States. However, it was so successful because his oral version was much cheaper than injectable vaccinations, and because they involved a live virus, they were able to confer herd

immunity in communities (Fox, 2013). Because his version of the vaccine was difficult to make in large quantities, a new solution was needed.

Dr. Jonas Edward Salk in the mid-twentieth century answered the call. In 1952 at the peak of the epidemic, polio had killed around three-thousand Americans, and 58,000 new cases were reported. The disease was causing more and more fear and illness among Americans and Salk worked toward a solution (science.jrank.org, 2019). He believed to make an effective vaccine, there had to be plenty of virus, it had to be grown on non-nervous tissue to avoid possible damage to human nerves, there must be a proper broth for growing the virus, three types of the virus had to be included in the same vaccine, and the virus must be killed or weakened but still left intact to stimulate the production of protective antibodies (Reidman, 1960).

In 1952, Salk was ready to test his first vaccine. He enlisted a person who had already had the polio virus to test it, and he would evaluate its effectiveness by measuring how their antibody level changed before and after receiving the vaccination. The vaccine worked, and Salk then looked to test it on patients who had not had the disease. He went into the Pittsburgh community and injected adults and children including his own three children. After vaccinating one-thousand subjects with his vaccine, it turned out to be completely safe and effective as the patients had developed antibodies against all three types of polio viruses while having no bad reactions to the injection. Salk was now ready for a mass trial of the vaccine, but he was also met with objections from some who believed that testing only one-thousand people was not enough to show the safety of the vaccine. However, Dr. Salk began his trial in April of 1954 after approval in hopes of slowing the outbreak that would happen as the warmer months began (Reidman, 1960).

Salk's trial began on April 26th, 1954 with 1,830,000 children taking part with their parent's permission. The vaccine was given to 440,000 children while 210,000 were given dummy injections. The other 1,180,000 received neither and were the control group. The children in this test were ages five to nine, and it took the effort of millions of people to make sure that this test was a success. Over one-hundred and fifty million pieces of data were sent to the Polio Evaluation Center at the University of Michigan to be evaluated, and on the morning of April 12th, 1955, the results were ready: it was determined that the Salk vaccine was sixty to ninety percent effective. Over six times as many more of the unvaccinated children were paralyzed by polio than among the vaccinated, and there was not a single death among the vaccinated group. Dr. Salk was praised for his work and even given a Congressional Medal of Honor by President Eisenhower (Reidman, 1960). However, his success took a turn for the worse when there was a tragic setback on his vaccine campaign.

Weeks after the announcement of the success of Salk's vaccine trials, there were reports that polio had developed in a number of children who had been vaccinated with Salk's vaccine. Further distribution was stopped and the vaccines that had been shipped were recalled. It was discovered that a batch of vaccine had not been completely inactivated and there was live virus still present in the vaccine. By the end of the incident, eleven people had died and over two hundred had developed polio (Reidman, 1960). This setback caused production problems with the Salk vaccine and it later was discontinued as a safe polio vaccine (science.jrank.org, 2019). Again, a new solution was needed to solve the polio problem.

In 1956, Dr. Albert Sabin tested his live oral polio vaccine on his wife and children with success, and the Soviet Union decided to put the Sabin Vaccine to the test with a mass trial. In June of 1959, the International Scientific Congress on Live Virus met in Washington, D.C. where Dr. Sabin announced that his live polio vaccine had been safely given to 4.5 million people (Reidman, 1960). By 1961, the United States licensed Sabin's oral vaccine for use and millions of Americans were vaccinated against polio (science.jrank.org, 2019). One advantage of the Sabin Vaccine over the Salk vaccine was that because it was a weakened live virus, it provided lifetime immunity and also provided protection to unvaccinated people in contact with those who were vaccinated (Reidman, 1960). Additionally, because it is taken orally, the Sabin vaccine was more convenient and less expensive than the Salk vaccine (science.jrank.org, 2019).

Regardless, a solution was finally found, and because of widespread vaccination efforts in the years following, polio was eradicated from the Western Hemisphere in 1994. Polio continues to circulate in small numbers in particular areas of the globe even today, which is why polio vaccination is still required for infants and children in the United States. However, vaccination programs are still working around the globe to eliminate these last strands of the virus for good (The College of Physicians of Philadelphia, 2019). The evolution of vaccinations has a long history, but it is evident that through the work of many scientists, researchers, microbiologists, doctors, and even ancient Egyptians and European royals, infectious diseases can be conquered through vaccination.

Evolution of Vaccines After Polio

After a solution to polio was found through Salk's vaccine and large-scale vaccine production was possible, disease control efforts continued through the creation of more and more vaccines that were being distributed around the globe. In the 1960s, the measles vaccine was developed and later turned into a vaccine created in 1971 that protected against both measles, mumps and rubella, more commonly known as the MMR vaccine. The recommended vaccines during this time included smallpox, DTaP (diphtheria, tetanus and pertussis), polio (IPV), and the MMR vaccine, and by the 1970s, one less vaccine was required: smallpox. Because of successful global eradication efforts, the smallpox vaccine was no longer recommended for use after 1972 (Offit, 2014).

A decade later, the vaccine for hepatitis B and *Haemophilus influenzae* type b (Hib) were created and added to the list of recommended vaccines. At first, it was only recommended that people who were directly at risk for hepatitis B such as infants whose mothers are hepatitis B antigen positive, healthcare workers, drug users, homosexual men, and people with multiple sexual partners get the vaccine; however, the immunization of only these high-risk groups did not effectively stop transmission, and the recommendation for vaccination was changed to include all infants (Offit, 2014).

In 1995 as more vaccines become available, the immunization schedule began being updated annually, allowing healthcare providers to have detailed information about who should receive each vaccine, age of receipt, number of doses, time between doses, and use of combination vaccines. Important changes to the vaccine schedule since 1995 include the introduction of the varicella (chicken pox) vaccine in 1996, the updated rotavirus vaccine in 1998, 1999, 2006, and 2008, the introduction of the hepatitis A

vaccine in 2000, and the pneumococcal vaccine in 2001. In addition, more recommendations for existing vaccine that extended to children included the influenza vaccine in 2002 and the hepatitis A vaccine in 2006. New versions of the existing pertussis (DTaP) and influenza vaccines were also created in 1997 and 2002, respectively, with the influenza vaccine being an intranasal version. Lastly, the oral polio vaccine was discontinued for use in 2000 after an injectable vaccine was preferred by most healthcare providers (Offit, 2014).

Today, there are ten recommended immunizations for infants, including polio (IPV), Hib, hepatitis B, Varicella, hepatitis A, pneumococcal, influenza, rotavirus, DTaP, and MMR. This list differs for adolescents, as adolescents, like adults, are recommended to get tetanus boosters every ten years after the first vaccination around age eleven. Other than this, most adolescents do not require additional vaccines unless they missed one from childhood. Although not required, the vaccine for meningococcus and human papillomavirus (HPV) has become more recommended over the past decade to protect young adolescents as they enter their teenage years (Offit, 2014).

Historically, most vaccines were deemed to be only for children. However, vaccines for adults are becoming increasingly common and necessary as well. Adults, especially those who are around infants, should get the Tdap vaccine as it protects against tetanus and pertussis, and in infants, pertussis can be fatal. The difference between the Tdap vaccine and the DTaP vaccine is that the Tdap one is approved for adults, as it is just a “booster” with a reduced dose, while the DTaP, although it protects against the same thing, is approved for children and is a full dose. In addition to these, the influenza vaccine is also recommended for all adults, adolescents, children, and infants over six

months, and the MMR and chickenpox vaccines are also recommended for adults who have not had the disease and the hepatitis A, hepatitis B, pneumococcus, and meningococcal vaccines, are also recommended for certain subgroups of the adult population. Lastly, the HPV and shingles vaccines are specifically recommended for certain age groups in the adult population. Unlike childhood vaccines that are often required for entrance to schools, adult vaccines are not mandated, leading to a lack of preventative healthcare measures through vaccine usage in the adult population (Offit, 2014).

Vaccine Types

A vaccine's composition influences the type of immune response it causes in the human body; therefore, they are classified into one of six categories: live attenuated, inactivated (or killed), protein subunit and toxoid, polysaccharide, conjugate, and recombinant. Live attenuated vaccines utilize viruses only and are made from a virus that are weakened to the point that it cannot cause disease, but it can create an immune response to protect one from the disease if exposed to it. With this type of vaccine, a weakened virus enters a cell and reproduces just enough to induce an immune response but not enough to infect many other cells and cause illness. Three different methods are used to make weakened viruses for this type of vaccine: the virus can be grown in nonhuman cells, it can be grown at a temperature lower than body temperature, or it can be grown using both human and nonhuman viruses. Examples of live virus vaccines include the rotavirus, MMR, and chickenpox vaccines (Feemster, 2018).

Inactivated, or killed vaccines are made from a whole virus or bacteria that has been killed or neutralized through the application of a chemical substance, usually

formaldehyde. Killed viruses are not able to reproduce and cannot cause infection or disease but can still create an immune response in the body, protecting it. Examples of this type of vaccine include the hepatitis A, polio, and most influenza vaccines. The third type of vaccine is called a protein subunit vaccine, which works by isolating the antigens or proteins on the bacteria that are known to be important for introducing a protective immune response. Some protein subunit vaccines, called toxoid vaccinations, target antigens known to act as toxins, inactivating the toxins that those bacteria produce, creating toxoids, or inactivated toxins. Examples of this include the diphtheria and tetanus vaccines. The pertussis vaccine is also a protein subunit vaccine that is made up of two to five different proteins that are either toxoids or part of the bacteria itself. These inactivated proteins cannot cause infection or disease but lead to an immune response that protects the host from the actual disease (Feemster, 2018).

Similar to protein subunit vaccines for bacteria, recombinant vaccines are made from individual proteins from viruses that are known to induce a positive immune response. These vaccines are made by inserting the gene that is responsible for making the selected protein into the DNA of a yeast cell, then as the yeast reproduces, the DNA reproduces as well, allowing the resulting reproduced protein to be grown and used in a vaccine. Both hepatitis B and human papillomavirus (HPV) vaccines are made through this technique (Feemster, 2018).

The last type of vaccine is the polysaccharide vaccine, which target a certain group of bacteria that have capsules around them that are made of sugars or polysaccharides. Because the capsule, or outer layer of the bacteria, is what the body interacts with first, it is also what the immune response targets. So, vaccines for this type

of encapsulated bacteria are made from the capsules rather than the proteins from the bacteria. A problem with this type, however, is that polysaccharide capsules do not induce immune memory well and they do not work well in children younger than two, making it difficult to protect young children against pneumococcus, meningococcus, and *Haemophilus influenzae b* (Hib). So, conjugate vaccines, an additional type, were created and allowed for the polysaccharide capsule to attach to a protein that is able to turn on memory cells, allowing a better immune response to the bacteria when exposed for a second time (Feemster, 2018).

In addition to these types of vaccinations that protect against individual bacteria or viruses, there are also combination vaccines, which protect against several. This method of combining vaccinations started in the early 1950s when there were only four vaccines available: diphtheria, tetanus, pertussis and smallpox. Instead of giving children four individual vaccinations, three of these vaccines, diphtheria, tetanus, and pertussis, were combined into one, forming the single DTaP vaccine. By the mid-1980s, there were seven vaccines: DTaP, measles, mumps, rubella and polio. So, the measles, mumps and rubella vaccines were formed to make one MMR vaccine, so children only received three vaccines but were protected against seven diseases. Since the 80s, several vaccines have been added to the schedule for children to receive and making combination vaccines has made this much easier. Today, there are several combination vaccinations on the market besides just the MMR and DTaP vaccines, again making vaccination children much easier (Offit, 2014).

Vaccine Components

Besides antigens, vaccines have several other ingredients that keep them safe and help to increase their effectiveness. These components include, preservatives, stabilizers, inactivating agents, and adjuvants. The preservatives include phenol and thimerosal, which are used to prevent vaccine contamination from any bacteria in the environment. Typically, these preservatives are most important in preventing contamination when the vaccine vial has been open for use, so typically these types of preservatives are only required in vials of vaccination and not in single-dose vaccines (Feemster, 2018).

One of the most common preservatives is thimerosal, which is a mercury-containing compound with high antibacterial factors. It has been used successfully since the 1930s in millions of doses of vaccinations, but because of the concern over small amounts of mercury in the vaccine, it is recommended that vaccines containing thimerosal as a preservative be given to infants over six months of age. Now, there are even thimerosal-free vaccines due to concerns, but it is important to note that there has been no case of mercury toxicity from any vaccines (Link, 2005).

The next component in vaccines are stabilizers, which include sugars, amino acids, or proteins, that act to keep the vaccine functional for long periods of time. Without these stabilizers, the antigens in vaccines would be degraded during the temperature changes that take place during the production, transportation, and storage of vaccines (Feemster, 2018). The third component of vaccines are inactivating agents, such as formaldehyde, that inactivate viruses or bacterial toxins for inactivated virus or bacterial toxoid vaccines. Formaldehyde is used during the production of some vaccines to inactivate, or kill, viruses or bacteria. So, although formaldehyde is removed from the

killed virus or bacteria, there can be a small amount of residue left behind in production. This amount left behind is much lower than the amount of formaldehyde that naturally occurs within the body (Feemster, 2018).

The last component of vaccines are adjuvants, which are substances that help to enhance the immune response to vaccines. This ingredient is especially important in the elderly and immunocompetent populations who may have weaker immune responses to vaccinations. Adjuvants also help to enhance the immune response to vaccines that only use a few antigens, but they are not needed in weakened or killed (inactivated) whole-virus vaccines that induce more complete immune responses. The most common type of adjuvant used in licensed vaccines in the United States are aluminum salts, because they help to boost immune responses by either stimulating the uptake of antigens by immune cells or by slowing the release of an antigen at the site of injection to promote a more sustained antibody production (Feemster, 2018). All of these components in vaccinations are necessary in ensuring the safety and effectiveness of vaccine production and have been heavily researched and tested over the years, ensuring their safety within the vaccines themselves.

Vaccine Schedules

Each year, the vaccine schedules for infants, children, adolescents, and adults are discussed and updated if needed. After they are discussed, the year's new versions are first recommended by the Advisory Committee on Immunization Practices and then approved by the Centers for Disease Control and Prevention, the American Academy of Pediatrics, the American Academy of Family Physicians, and American College of Obstetricians and Gynecologists before being published on the CDC's website (National

Center for Immunization and Respiratory Diseases, 2019). The vaccine schedules indicate the recommended ages for routine administration of currently licensed vaccines for infants, children, adolescents and adults. Any dose not administered at the recommended age should be administered at a later visit, when indicated in the timeline in the schedule (American Academy of Pediatrics, 2019).

The following tables outlining the vaccine schedules on the CDC's website (2019) are included in the Appendix: **Table 1a -** Recommended Child and Adolescent Immunization Schedule for ages 18 years or younger**,** United States, 2019**, Table 2a -** Catch-up immunization schedule for persons aged 4 months-18 years who start late or who are more than 1 month behind, United States, 2019**, Table 3a -** Recommended Child and Adolescent Immunization Schedule by Medical Indication, United States, 2019, **Table 1b -** Recommended Adult Immunization Schedule by Age Group, United States, 2019, **Table 2b -** Recommended Adult Immunization Schedule by Medical Condition and Other Indications, United States, 2019.

Vaccination Disasters

Vaccines are considered to be the most revolutionary and important medical discovery by many. However, it took several trials and errors to get where we are today in ensuring the safety of vaccinations. We can look at several cases of vaccine disasters throughout history and learn from them not for the purpose of discouraging vaccinations, but to show that there have been many mountains climbed and lessons learned that have all lead to the production of safe and effective vaccines that keep us healthy today (Link, 2005).

Marblehead, Massachusetts, 1800

In July of 1800, Edward Jenner sent a sample of smallpox vaccine to Benjamin Waterhouse in Marblehead, Massachusetts in order to initiate a vaccine program. Unbeknownst to either, the vaccine that Jenner gave Waterhouse contained an attenuated (weakened) smallpox virus that reverted to full virulence, ultimately killing sixty-eight people that Waterhouse had vaccinated in an effort to protect them from smallpox (Link, 2005).

Bremen, Germany, 1893

During a smallpox vaccination campaign in the Port of Bremen in 1893, 1,289 shipyard workers were vaccinated. But apparently the same serum was passed from one patient's pustules to the next patient, causing 191 of the vaccinated men to develop hepatitis and jaundice, or yellowing of the liver, within eight months of the procedure. It was concluded that the men had experienced a form of hepatitis transferred by human lymph fluid, leading to our understanding now that some chronic disease can be transferred by blood, allowing us to further understand diseases that were caused by blood-borne pathogens. This marked an important discovery in medicine, but did come at a cost (Link, 2005).

St. Louis, Missouri, 1901

In 1901, diphtheria antiserum was derived from the serum of horses that had been immunized with the diphtheria toxin. In this particular case, the horse in which they were making the antiserum from had developed tetanus, and before he developed symptoms of the disease, his blood was drawn to prepare the diphtheria antiserum for the vaccines.

Because there was no way to know that the horse's blood already contained the tetanus toxin, twenty children who were vaccinated from the infected horse's diphtheria antiserum became ill, and fourteen later died from the paralytic effects of tetanus (Link, 2005).

Dallas, Texas, 1919

This disaster was caused by another rogue diphtheria vaccine gone wrong. A new type of diphtheria vaccine, called TAM, was developed that contained a mixture of diphtheria toxin and antitoxin that was meant to stimulate antibodies but not poison the child because of the protective effect of just the right amount of antitoxin. However, this was a fine balance because if it was thrown off in the slightest bit, the child would be exposed to the deadly diphtheria toxin. Between October 23rd and November 13th, 1919, the city of Dallas Health Department injected over three-hundred children with the TAM diphtheria vaccine. Of these, one-hundred twenty became ill and ten later died. This TAM approach to the diphtheria vaccine was abandoned in the 1920s due to many deaths reported from the vaccine (Link, 2005).

Lubeck, Germany, 1929

In 1919, tuberculosis was rampant in Europe and lead to many deaths. During this year, Albert Calmette, a student of Louis Pasteur's, along with Camille Guerin, spent years developing a tuberculosis vaccine. They found that cow tuberculosis bacterium lost its virulence when grown through many generations in a medium containing bile, but that it could still evoke an antibody immune response in humans. So, they created a vaccine, the earliest of which were taken by mouth, but later given by injection. In 1929, Calmette

received a request for a tuberculosis culture that he and Guerin had created from the director of public health in Lubeck. The culture was sent, and labs in Lubeck prepared the vaccine and gave it to 242 children (Link, 2005).

Within weeks, seventy-two of these children were dead from tuberculosis. At first, Calmette and Guerin were blamed for the disaster, but it was later found that the Lubek lab directors had accidentally contaminated the cultures with a virulent strain of the human tuberculosis bacteria. The two men in charge of the lab were convicted of criminal behavior and jailed, and the Bacille Calmette-Guerin (BCG) vaccine for tuberculosis became used extensively worldwide (Link, 2005).

Bundaberg in Queensland, Australia, 1928

Bundaberg, a city of approximately 43,000 people, was constantly plagued by diphtheria at this time, so any attempt to fix the problem was welcome. On January 12th, 1928, twenty-one children received the diphtheria vaccine and within hours became violently ill. Twelve later died. This disaster was not because of the vaccine itself, but because it had become contaminated with staph bacteria, most likely causing toxic shock syndrome among those who received the vaccine (Link, 2005).

Yellow Fever II: Hepatitis, 1942

An epidemic of hepatitis began in March of 1942 among United States army personnel, ultimately leading to the hospitalization of fifty-one thousand troops during the next seven months and one-hundred and fifty deaths. The hepatitis emerged several weeks after the administration of a vaccine for yellow fever. At the time, the vaccine contained human blood serum, which carried the hepatitis virus. The human serum from

the original vaccine came from medical student volunteers, one of which was ill at the time of donation while several others had a history of hepatitis. This disaster is the largest hepatitis epidemic ever recorded (Link, 2005).

Kyoto, Japan, 1948

In October of 1948, more than fifteen-thousand babies and children in Kyoto, Japan were injected with a diphtheria toxoid vaccine, and 606 later became ill, and around sixty-eight died. These deaths were caused by the diphtheria toxin not being fully neutralized in the vaccine (Link, 2005).

SV40, 1950

The mid-twentieth century was filled with constant fear of polio and prompted scientists to find quick solutions. When the Salk polio vaccine was finally licensed for use, it was given to as many as ten million people, mostly children, between 1955 and 1963. What many did not know at the time, however, was that by receiving this vaccine, they were also receiving a dose of a live monkey virus called SV40. The polio vaccine was prepared from cultures from rhesus monkey kidneys, and unknown to scientists, the vaccines were contaminated with the SV40 virus that otherwise go undetected in monkeys (Link, 2005).

The SV40 virus can cause cancer and is often found in various human cancers. So, because of the early polio vaccine, the SV40 virus was introduced into the human population and since then, the infection is able to be transmitted from person to person. So, although the original polio vaccines contained SV40, the ones made after 1963 went through a screening process to detect the virus, making all polio vaccines from then on

free of SV40. However, because the virus was already introduced into the human population, it has continued to spread and can still be seen in people with cancer even today (Link, 2005).

The Cutter Incident, 1955

As mentioned previously, in the spring of 1955, the Salk polio vaccine, which had an inactivated polio virus, had been tested on hundreds of thousands of volunteers and declared safe and effective. Its licensure was welcomed reverently and was called one of the greatest achievements in medical science. People were overjoyed to have a preventative measure against the paralyzing polio virus. However, before the vaccine became a major success, it did have some downfalls. On April 25th, two weeks after the release of the vaccine, an infant with paralytic polio was admitted to a hospital in Chicago after being vaccinated for polio nine days before. Five similar cases were also reported nine days after vaccination that caused paralysis. An investigation by epidemiologists quickly uncovered a connection between the cases and vaccines prepared by Cutter Laboratories, and two days after the first case, Cutter recalled all of their polio vaccines (Link, 2005).

While this event was unfolding, a related event happened. About two weeks after the first wave of cases, a second, larger wave was occurring, and family and community members of the original group that was ill started to get sick. It was discovered that the Cutter vaccine contained live, virulent polio that not only infected the recipients of the vaccine, but also the family and community members surrounding the recipient. The formaldehyde step in these vaccines was done incorrectly, so the live virus was not killed.

The Cutter epidemic was soon contained, but it resulted in around 460 polio-infected children before it was all over (Link, 2005).

Yellow Fever I: Avian Leukosis, 1960

Yellow fever, a viral tropical disease transmitted by mosquitoes and then man to man and closely resembles symptoms of the flu, had been wreaking havoc on tropical societies since the seventeenth century. It ultimately leads to jaundice and later death, which is why it was nicknamed yellow fever. It caused problems in several American port cities in the twentieth century, and scientists pushed to find a solution. In 1930, a highly effective and safe vaccine was created. It was not until 1966, however, that researchers realized that the vaccine had been contaminated by a bird virus, avian leukosis, which causes various cancers in birds and can cause cancers in humans as well. Millions of people received the vaccine in the 30s without obvious harm and were protected from yellow fever. But it is hypothesized that the avian leukosis in these early yellow fever vaccines could have been a contributing factor for an increased incidence of cancers among people twenty years after receiving the vaccination. It is not one-hundred percent connected, but this coincidence is important to consider when looking at the effects of early vaccines (Link, 2005).

"Atypical" Measles, 1960s

The live measles vaccine was licensed in 1963 in addition to a killed, inactivated, version of the vaccine. People usually preferred the killed virus vaccine at this time because it just seemed like the safer option, but that was not always the case. Tested on children, the killed vaccine showed that there was a brisk antibody response with minimal

side effects, so it was widely used. However, within a year or two, measles cases began to pop up in immunized children and isolated epidemics began to occur. This killed vaccine was not preventing measles, and it was discovered that the reason behind it was that the antibodies rapidly disappeared in the vaccinated children, so by one year later, the children were no longer protected, even after booster doses (Link, 2005).

In 1967, Vincent A Fulginiti, a pediatrician at the University of Colorado in Denver, reported on a series of children who contracted measles five years after vaccination, saying that these children had a "new disease termed atypical measles" (p. 32). The symptoms of this atypical strain were high fever lasting four to seven days, headache, muscle pain, severe pneumonia, pleurisy and a rash that spread from the feet to the neck. They became ill enough to need hospitalization but recovered. In addition, most children who had developed this "atypical" measles had received the live virus vaccine after being immunized with the killed vaccine, causing the harsh reaction to the live vaccine. It was later theorized that the killed vaccine had somehow sensitized the children to the measles virus so that they were able to get the atypical strain when exposed to the live measles vaccine. After this development, Fulginiti wrote, "It is our conclusion that no healthy child should electively receive killed-measles vaccine" (p.33) and the vaccine was withdrawn from production. Since then, the atypical measles virus has not been seen again (Link, 2005).

Swine Flu Fiasco, 1976

In the winter of 1976, an epidemic of respiratory infections affected around five-hundred soldiers at Fort Dix in New Jersey. One of the soldiers became critically ill and died within twenty-four hours, and it was determined that a strain of the flu virus was

responsible that closely resembled the 1918 strain that infected 20 million people worldwide. The possibility of another pandemic influenza like 1918 alarmed health officials, but there were only cases of this new strain present at Fort Dix. Nevertheless, the Centers for Disease Control and Prevention (CDC) recommended a national swine flu immunization policy, presenting President Ford with a $136 million plan to immunize every person in the United States (Link, 2005).

There was tremendous pressure on vaccine companies to produce this much product, and it did not help that the insurance companies refused to provide liability coverage for vaccine manufacturers. The vaccine production companies refused to distribute the vaccine without liability protection, but, the political pressure was too strong, and Congress passed the Swine Flu Act of 1976, which provided for the federal government to assume the liability for any vaccine mishaps. The first batch of the new vaccine produced no antibodies to swine flu as the CDC had given the manufacturer the wrong strain of the flu virus, causing two-million useless doses to be wasted. Subsequent batches of the virus only provided adequate antibody levels when large doses that produces many side effects were used (Link, 2005).

Eventually, the program started on October 1st, and two weeks later, three elderly people in Pittsburgh, Pennsylvania died within hours of receiving the swine flu vaccine. The Program was then suspended in Pennsylvania and in several other states, but the program was still recommended by the CDC and President Ford, so it persisted everywhere else. A month later in November, reports came in of people suffering from neurological damage, later identified as Guillain-Barre syndrome (GBS), after receiving the swine flu vaccine. This disease can cause paralysis and death if not properly treated.

This GBS epidemic put an end to the swine flu immunization program and it officially ended on December 6th, 1976. The whole program started with a reasonable concern that a flu pandemic might occur from the flu occurring in Fort Dix, but it was soon taken too seriously and blown up to monstrous proportions, in the end causing fifty-three deaths among the 43 million who were vaccinated. Most GBS patients made a full recovery, but it could have been much worse (Link, 2005).

Jordan, 1998

On September 28th, 1998, the annual Jordanian process of immunizing children began with the start of the school year. A day later, two boys came to school complaining of being dizzy and fainted. Health officials arrived, and twenty other students had also fainted from the mysterious illness. By the end of the day, eighty students were hospitalized and by the next day, that number rose to 122. All had been vaccinated with a well-established tetanus and diphtheria (DTaP) vaccine and all were home and healthy 24 hours after falling ill (Link, 2005).

All of the children affected had received the vaccine the day before, and no child who did not get the vaccine was affected. One batch of the vaccine was associated with more cases than other batches, and of the first fifty-five children, 58 percent had fever, 15 percent had chest tightness and needed oxygen, and 13 percent had abnormal EKGs. Most of the symptoms were mild and were symptoms that were often associated with this type of DTaP vaccine, so one or two children with these symptoms would not have raised much concern. It seemed that the vaccine itself did not cause the illness among all these children, but rather, the panic from the school staff that caused the children to act in a

way that looked as if they became ill. It was determined that this was biologically impossible that all of these children became sick at the same time, and that the reaction of the school staff to the first two boys who were actually sick prompted more children to "fake it" essentially. So, it was concluded that there was no unusual adverse reaction to this vaccine after all (Link, 2005).

China, 2002

China has an active immunization program, but something went wrong in 2002 in the city of Mishan. 8,300 children aged seven through sixteen received the killed-virus Japanese encephalitis vaccine. Japanese encephalitis is a mosquito-borne viral illness that is very common in Asia. A majority of infections cause no symptoms or just a flu-like illness, but in some cases, encephalitis, or swelling of the brain, can occur, causing severe brain damage and often death. After the immunization of the 8,300 children, nine-hundred were hospitalized, and some became seriously ill. It is not clear what had exactly happened, and researchers are still looking into this vaccine disaster (Link, 2005).

Vaccines for the Future

In his 2010 article, Gary Finnegan asked the important question, "The development and widespread adoption of vaccines has been hailed as the public health triumph of the 20th century, but what does the future hold?" We have seen the successes of vaccines in combating infectious diseases like polio and smallpox. However, what does the future hold for the prevention of other diseases such as cancers, tuberculosis, and Alzheimer's?

Gregory Poland and Alan Barrett, at the Mayo Clinic and the University of Texas Medical Branch respectively, published an article in 2009 outlining the successful vaccines of the 20th century and approaches for making future vaccines for important disease of the 21st century. In this article, they outline that in the twentieth century, 31 vaccines that prevented acute infectious diseases were licensed in the United States and that in the twenty-first century, the challenge of developing vaccines for chronic infectious and noninfectious diseases is becoming increasingly important as morbidity and mortality due to these conditions are becoming an ever-increasing public health problem, with ensuing hefty economic costs to Americans. Poland and Barrett agree that in the twenty-first century, the approach to how we make vaccines needs to change in order to combat these different illnesses, and that the approach includes enhancing the immune response of vaccines through three different approaches: adjuvants, prime-boosting strategies, mucosal immunity, and also through the addition of therapeutic vaccines for chronic diseases (Poland & Barrett, 2009).

The first approach to improving immunogenicity, which is the ability of a vaccine to provoke an immune response in the body, as laid out by Poland and Barrett (2009) is through adjuvants and the increased use of them to have this immune response. Second is the use of prime-boost regimens, which when used in heterologous vaccines can improve immunogenicity greatly in both chronic infectious and noninfectious diseases. Next is mucosal immunity, which is important when we consider the effectiveness of nasal and oral vaccinations that can continue to be used and developed in the 21st century. Lastly, therapeutic vaccines have started to become more popular in the hope that chronic noninfectious diseases such as Alzheimer's can be prevented. These therapeutic vaccines

have been developed to target plaque buildup between neurons in the brain, which degenerates the brain and can lead to Alzheimer's. These have not been super successful, but they are something to consider when we think about the potential for vaccines in the future (Poland & Barrett, 2009).

The growing cost of caring for our aging population, where noninfectious diseases like Alzheimer's and dementia are becoming increasingly common, is creating a new need in the evolution of vaccines. But, the complexity of these diseases makes it hard for vaccines to be created. In addition, vaccines for cancer are always being researched. The HPV vaccine created hope that other cancer vaccines can be created, but they are often much more complicated, which is why we do not have vaccines for cancer - yet. Additionally, scientists are constantly battling the human immunodeficiency virus (HIV) and yearning for a vaccine solution, but because HIV is a viral infection, it presents a new set of challenges (Finnegan, 2010)

The National Institute for Allergy and Infectious Diseases (2008) also has ideas for vaccines for the future, mentioning that vaccines delivered through a needle have shortcomings, including that they must be kept sterile and must be administered by medically trained personnel, making vaccination measures somewhat challenging in the case of a widespread outbreak. Because of this, scientists are investigating new ways to deliver vaccines, including through the use of edible vaccines, patch and nasal mist vaccines, and universal and therapeutic vaccines (The National Institute for Allergy and Infectious Diseases, 2008). Overall, the success of vaccine development in the twentieth century has laid the groundwork for the battle against infectious diseases and the attempt to control chronic infectious and noninfectious diseases in the 21st century (Poland

& Barrett, 2009).

It is clear that in the twentieth century, vaccination was known as the greatest revolution in health. Mixed with the success of increased hygiene habits among people and the development of antibiotics, vaccination led to the elimination of many childhood infectious diseases in America (Rappuoli, 2011). In the twenty-first century, the hope is that vaccination will fully eradicate remaining childhood infectious diseases, but this goal does come with challenges. As the anti-vaxx movement has swept across the globe, the question of why people resist vaccination needs to be discussed in order mitigate the resistance towards vaccines that many have. Additionally, the question of what policies can be introduced to mitigate this resistance and that aim to increase public trust in vaccination needs to be discussed so that vaccines can be perceived among all as the best way to keep out country and our world healthy.

Chapter 4

Findings

Evolution of Vaccine Resistance

Fear of vaccines and myths against them are not a new phenomenon. In fact, opposition to vaccines can be seen as far back as the eighteenth century in England, when Reverend Edmund Massey called vaccines "diabolical operations" in his 1772 sermon, "The Dangerous and Sinful Practice of Inoculation." The main argument at that time was that vaccines went against God's plan, and similar opposition was seen in Massachusetts around the same time with Reverend John Williams, who said that vaccines were the devil's work. However, opposition began to shift from religious arguments to political and legal arguments a century later (A. Hussain, Ali, Ahmen, & S. Hussain, 2018).

In the mid nineteenth century, there was growing attention toward the new idea of public health after the introduction of the first vaccine by Edward Jenner. Local and national governments became interested in the health of the people living in their communities and countries for many reasons, but mainly due to the fears that disease would lead to a breakdown of the social, religious and economic order (Blume, 2017). So, many governments began initiating vaccine programs and vaccinated a majority of their citizens.

In the 1830s after an initial generation had been vaccinated and the incidence of smallpox declined in the United States and in Europe, the first anti-vaccination, or anti-

vaxx movement, emerged (Stern & Markel, 2005). The unpopularity of vaccination was due in part to the procedure itself in that it involved scraping the arm to break the skin before applying the vaccination to the open wound. It was often badly done and left people with large scars (Blume, 2017). Others opposed the method because they considered vaccination as an intrusion of privacy and bodily integrity or because they had sanitary, religious, scientific, or political objections (historyofvaccines.org, 2018). Two primary themes can be seen throughout anti-vaxx movements of the past and even the present: first, the perception that vaccines cause more harm than the diseases that they were made to prevent, and second, the close association between promotion of vaccines and the introduction of compulsory vaccination policies (Schwartz, 2012).

The first compulsory vaccination law for smallpox was passed in 1827 in the United States in Boston, Massachusetts, requiring the smallpox vaccination in order for children to attend school. After the introduction of this policy in Boston, the practice spread throughout the country and the world by the end of the nineteenth century (Schwartz, 2012). In 1853 in England, a similar compulsory vaccination law, entitled "the Vaccination Act of 1853" was passed and required vaccination for infants up to three months old, and the Act of 1867 extended this age requirement to 14 years, adding penalties for vaccine refusal (historyofvaccines.org, 2018). Parents or guardians who failed to vaccinate their children in their first three months of life were subject to fine or imprisonment. Although the number of cases of smallpox were steadily decreasing, a number of people spoke out publicly against compulsory vaccination, either because they thought the inoculation method was unsafe or because they opposed the involvement of the government in the field of health, especially when it came to the decisions about

one's body. The opposition continued, but similar compulsory laws were put into place in other European countries anyway. For example, in the Netherlands, despite objections from Protestant communities, a law was created in 1872 that required proof of vaccination before a child could be admitted to school. Because of this policy, the rate of vaccination rose to ninety percent (Blume, 2017).

In Germany, there had been ideas that the health of a population wasn't the responsibility of the state. However, opinions gradually shifted to favor compulsory vaccination to model what other countries had successfully been doing, and the Imperial Vaccination Law of 1874 made vaccination compulsory in Germany. Other countries such as the United States, India, and Brazil followed suit and also created their own compulsory vaccination laws, but they were still met with some opposition (Blume, 2017).

The original anti-vaxx organization, the Anti-Compulsory Vaccination League was established in the United Kingdom in 1866 to protest the compulsory smallpox vaccination laws. In the United States, the Anti-Vaccination Society of America was formed in 1879 and the American Medical League was founded a few years later. There are some similarities and differences between the opposition to vaccination in different periods of history. In the 19th century, vaccine resistance was mainly due to the concern about the safety and efficacy of vaccines, which was a largely unregulated industry at the time, coupled with the opposition of the extension of government into the lives of citizens. At this time, the opposition was mainly aimed at the smallpox vaccine, because it was the only one available (Vanderslott & Roser, 2015). Even though there was opposition to these laws, nations responded by articulating that they possessed the right to

protect the common good and the health of all citizens, further advocating for compulsory vaccine laws. The reasons for opposition shift in the 20th and 21st centuries will be mentioned in a later section.

Court Cases

By the beginning of the twentieth century, nearly half of the states in the United States had requirements for children to be vaccinated in order to attend school (Malone & Hinman, 2003). In 1902, following a smallpox outbreak in Cambridge, Massachusetts, the Board of Health of the City of Cambridge mandated all city residents be vaccinated against smallpox. Henning Jacobson, a Cambridge resident, refused vaccination, saying that the law violated his right to care for his own body. In turn, the City of Cambridge filed criminal charges and was persecuted in the local court system. After losing his court battle in the local court, Jacobson appealed to the United States Supreme Court (historyofvaccines.org, 2018).

Jacobson v. Massachusetts, 1905

In 1905, the U.S. Supreme Court, in *Jacobson v. Massachusetts*, ruled in favor of the State of Massachusetts' compulsory vaccination law, citing that the need to protect the public's health through mandating the smallpox vaccine outweighed an individual's right to choose. This was the first U.S. Supreme Court case concerning the power of states in public health law (historyofvaccines.org, 2018). The Court held that a health regulation requiring the smallpox vaccination was a reasonable exercise of the State's power and did not violate the rights of individuals under the Fourteenth Amendment to the U.S. Constitution because "such reasonable regulations established directly by

legislative enactment as will protect the public health and the public safety." The Court also rejected the idea of vaccine exemption because it "would practically strip the legislative department of its function to care for the public health and the public safety when endangered by epidemics of disease" (Malone & Hinman, 2003). This tenet of protecting the health of the public over the right of the individual has been consistently reiterated in the argument for vaccines, bolstering the idea of "herd immunity," which is when a high percentage of a population, usually around 85-90%, are vaccinated in order to protect the entire population and those who are unable to be vaccinated within a group (Stern & Markel, 2005).

Following the 1905 Supreme Court Ruling in *Jacobson v. Massachusetts*, there was even more opposition. A 1906 news report from Yolk, Pennsylvania, entitled "Vaccination Stirs Revolt," reported "Threats to burn schoolhouses, whip teachers, and punish school directors have been the outcome of the enforcing of the compulsory vaccination law" (Schwartz, 2012). People were upset that they had to get vaccinated for various reasons, but the health of the general population was at stake, which is why these compulsory laws remained in effect.

Zucht v. King, 1922

In 1922 with *Zucht v. King*, the Supreme Court addressed the constitutionality of vaccination requirements once again. The Court denied a due process Fourteenth Amendment challenge to the constitutionality of city ordinances that exclude children from attending school for not providing evidence of vaccination, holding that "these ordinances confer not arbitrary power, but only that broad discretion required for the protection of the public health" (Malone & Hinman, 2003). In this case, the Supreme

Court unanimously upheld the local government's mandate requiring vaccination for public school attendance, giving precedent for state and local municipalities to develop their own standards for immunization requirements, allowable exemptions, and enforcement mechanisms (Feemster, 2018).

Commonwealth v. Green, **1929**

In October of 1929, a court case in the Massachusetts Supreme Judicial Court entitled *Commonwealth v. Green* outlined a case in which a parent refused to vaccinate his children and therefore did not send them to school. In this case, the defendant was convicted of failing to send his two children to school, saying that "he refused to have his children vaccinated and that he knew that the authorities would not allow them to attend school unless vaccinated." The conviction was upheld by the court, and data collected showing "Deaths During Week Ended November 30, 1929" was attached to the record in an attempt to show the importance of compulsory vaccine laws in hopes of decreasing opposition (Court Decisions Relating to Public Health, 1929).

Prince v. Massachusetts, **1944**

Further authority to require the vaccination of children came under the *parens patriae* doctrine, which asserted the authority of states over child welfare. In 1944 in the case of *Prince v. Massachusetts,* the Supreme Court summarized the doctrine, saying

> Neither rights of religion nor rights of parenthood are beyond limitation. Acting to guard the general interest in youth's well-being, the state as *parens patriae* may restrict the parent's control by requiring school attendance, regulating or prohibiting the child's labor, and in many other ways. Its authority is not nullified

> merely because the parent grounds his claim to control the child's course of conduct on religion or conscience. Thus, he cannot claim freedom from compulsory vaccination for the child more than for himself on religious grounds. The right to practice religion freely does not include liberty to expose the community or the child to communicable disease or the latter to ill health or death. (Malone & Hinman, 2003, p. 273).

In this case, the Court's ruling had large implications for a parent's right to refuse vaccination for their children based on religious beliefs. The case focused on a Jehovah's witness parent who claimed the right to have her child distribute religious pamphlets on the street, and the Court ruled this as a violation to child labor laws, saying that religious freedom did not trump child labor laws. By doing this, the Court also spoke on vaccine refusal and religious beliefs, as stated above (Feemster, 2018).

This case also points back to the Fourteenth Amendment's equal protection clause, and that every person, including children, should have equal protection from harm. So, because vaccines are meant to protect one from the harm of vaccine-preventable diseases, the clause implies that a decision not to vaccinate a child violates that child's right to be protected. Even with these precedents, immunization requirements did not become a central feature of United States vaccine policy until the 1960s and 1970s, when states began to enact legislation in response to measles outbreaks. Prior to that time, many health departments only required immunization in response to outbreaks, not to prevent them before they started. Now, state legislatures require vaccination as a condition of school attendance to prevent outbreaks of vaccine-preventable diseases (Feemster, 2018).

Return to Vaccine Policy: Peace and Protest

In the 1920s and 1930s, the Anti-Vaxx movement rose to new heights as progressive thinking took over, leading many to mistrust the growing medical profession and dislike the change in the government's role as it began to interfere more in the lives of citizens. This, coupled with the Great Depression, made many believe that the government and the medical profession had no right in telling its citizens what they can and cannot do. However, anti-vaccine thinking began to decline in the 1940s for three reasons: a boom in medical knowledge, specifically in vaccine science, discovery and manufacturing; increased public awareness of widespread infectious disease outbreaks and the need to protect children from the threat of disease; and a baby boom coupled with increasing levels of education and wealth among people. All of these things led to more public acceptance for vaccines in the 40s and resulted in lower levels of disease outbreaks, illnesses, and deaths (Poland & Jacobson, 2011). In the years leading up to the 1960s, a series of new vaccines that prevented polio, measles, mumps, and rubella, were developed, and they were greeted with great enthusiasm by parents who lived in fear that their children could be sickened (Conis, 2019). By 1963, twenty states, the District of Columbia, and Puerto Rico had compulsory vaccination laws for several different types of vaccinations, requiring children to be vaccinated in order to be able to attend school (Malone & Hinman, 2003).

As the 1960s began, public health officials believed that because new vaccines, especially the polio vaccine, were greeted with such positivity in the past, that these new vaccines would attract the same enthusiasm (Conis, 2019). However, they were wrong. As the prevalence of disease began decreasing, so did the belief among the public that

vaccines were important and necessary, leading many to disregard getting their children vaccinated (Poland & Jacobson, 2011). Families that were used to living with the threat of measles dismissed the new vaccine against the disease thinking it wasn't necessary, and middle-class parents usually only got their children vaccinated with these new vaccines if the family doctor recommended, which did not always happen (Conis, 2019).

This sentiment among the public, along with the development of more vaccines and the addition of them to the vaccine schedule, as well as the media perpetuating the dangers associated with vaccines, led to the anti-vaxx idea to once again spread and flourish in the 1970s (Poland & Jacobson, 2011). This shift in the nation's vaccine agenda coincided with an increase in social movements that encouraged Americans to question authority and sources of expertise in the medical practice. Women pushed back against the patriarchy, environmentalists pushed back against the nation's growing industry, and patients pushed back against doctors as the vaccine schedule and compulsory laws expanded, causing a growing number of pushback against vaccines. The prevalence of infectious diseases began to increase once again among all classes, lower, middle and upper. As health officials tried to revamp the vaccine rates in order to decrease these infection rates through promotional propaganda, they realized that their plan was not working, and ultimately decided to return to implementing policies that required vaccination (Conis, 2019).

This signaled a new era of vaccination in the United States for four reasons: the federal government was assuming an increasingly prominent role in determining vaccination policy; vaccines increasingly targeted diseases that medical experts once considered "mild"; vaccination campaigns aimed not to just reduce disease, but to

eradicate it; and an increasing reliance on the vaccination of children through mandatory school vaccination laws in order to ensure a society free of preventable infectious disease (Conis, 2019). In the 1970s, states that had compulsory vaccination laws for the measles vaccine in place for children to attend school had measles incidence rates that were forty to fifty percent lower than states without compulsory vaccination laws. In 1976 and 1977, there were measles outbreaks in Alaska and Los Angeles, leading health officials to more strictly enforce these compulsory vaccine laws in these areas (Malone & Hinman, 2003).

Once enforcement began in Alaska, 7,418 students out of 89,109 total students, or around eight percent, failed to provide proof of vaccination and were not allowed to attend school. One month later, only fifty-one students still had not been vaccinated and were still unable to attend school, and no further cases of measles occurred. On the other hand, in Los Angeles, approximately 50,000 students out of 1.4 million total students, or four percent, were unvaccinated. After most were vaccinated and returned to school, the number of measles cases dropped dramatically, demonstrating that compulsory vaccination laws could be enforced and were effective (Malone & Hinman, 2003).

Because vaccination levels in children were declining everywhere throughout the United States at this time, not just in Alaska and Los Angeles, a nationwide vaccination program, called the Childhood Immunization Initiative, was created in 1977 to attempt to raise vaccination levels to ninety percent by 1979. This initiative supported the enactment and enforcement of school vaccination requirements, and during a two-year period, more than 28 million records of schoolchildren were reviewed, and the vaccination process began. An analysis of six states that strictly enforced compulsory vaccine laws during the 1977-1978 school year compared to the rest of the United States showed incidence rates

of disease that were half of those of the rest of the country. A school year later after the Childhood Immunization Initiative was put into place, the incidence rates were less than one-tenth of those of the rest of the country. By the 1980-1981 school year, all fifty states had compulsory vaccine laws, and since 1981, vaccination levels in schools have been 95% or higher for the DTaP, polio, and MMR vaccines (Malone & Hinman, 2003).

In the 1970s and 1980s, the diphtheria, tetanus, and pertussis vaccine was questioned in connection with permanent brain injury, but studies showed no connection (Vandersloot & Roser, 2015). However, the public was still scared of these claims, and a 1982 television documentary, entitled *DPT: Vaccination Roulette,* became a turning point in the modern history of vaccine safety controversies. The program featured emotional stories of children believed by their parents to have been harmed by the diphtheria, tetanus, and pertussis combination vaccination (Schwartz, 2012).

This program led to a national debate on the use of the vaccine, even though the program was just a collection of unproven claims. However, it led to many countries stopping their DPT vaccination programs as public protests became strong, leaving behind a period in which pertussis had been well-controlled through vaccination. Countries that dropped routine pertussis vaccination due to this program had a large increase in the incidence of pertussis compared to countries that retained their high immunization rates. Ultimately, these countries that eliminated their vaccine programs ended up reinstating them (Poland & Jacobson, 2011) One of the groups that came from the popularity of *Vaccine Roulette* was called Dissatisfied Parents Together, which was a group of parents that advocated for safer vaccines, greater government oversight over vaccination, and federal compensation for the families of children harmed by vaccines.

This group helped to pass the National Childhood Vaccine Injury Act of 1986 (Conis, 2019).

The Anti-Vaxx Movement Reaches New Heights

As the 1990s approached, the anti-vaccination movement continued to accelerate due to a few reasons. First, the chickenpox, hepatitis A, and rotavirus vaccines were licensed in this decade, and many parents believed that the diseases that these vaccines prevented were minor and became increasingly skeptical about the necessity of the continued use of vaccines. Secondly, during this time, people began to become more concerned about chemicals in processed foods and in the environment, and they also were more concerned about the ingredients in vaccines. In this decade, the demand for organic and natural products increased dramatically. Third, the passage of the 1994 Dietary Supplement Health and Education Act required the United States Food and Drug Administration to regulate nutritional supplements as foods rather than apply more regulations on them used to verify the safety of pharmaceutical drugs. So, demand for nutritional and herbal remedies exploded among consumers who thought they were safer than traditional drugs and could be used to replace them. Fourth, the practice of alternative medicine including holistic healing, chiropractic medicine, herbal treatments, and others became more popular. Lastly, purchasing home computers became more affordable, making the internet available to more people. So, families began having easy access to the internet from their own homes and public blogs and websites became common ground where people shared information on certain topics, allowing anti-vaxxers to connect and further promote their views over the web (Davidson, 2018).

Andrew Wakefield's 1998 Study

These factors helped to gather more support for the anti-vaxx movement in the 1990s, but it did not stop there. In 1998, a spark came that lit the fuse to the anti-vaxx movement that continues around the world until this day, and that spark came from a member of the traditional medical community (Davidson, 2018). British physician and researcher Andrew Wakefield ignited the controversy over the link between vaccines and autism when he announced that he had uncovered evidence that the measles, mumps, and rubella (MMR) vaccine inflamed and damaged the digestive systems of children, allowing toxins and chemicals to enter the bloodstream and damage the brain, leading to autism (Goldberg, 2010).

As a researcher at the Royal Free Hospital in London, Wakefield called a press conference to announce the findings of the research conducted by him and twelve colleagues that showed that the MMR Vaccine was associated with the development of autism and intestinal problems in children. He specifically identified the measles component of the combined MMR vaccine as the problematic element. The British media treated his announcement as credible and newsworthy because the research was published in the credible, peer-reviewed journal, *The Lancet,* and the news spread like wildfire (Davidson, 2018).

The story spread across Europe, Australia, Japan and eventually landed in the United States (Davidson, 2018). The damage was done, and the MMR vaccine rates began to plummet in Britain, Ireland, the United States, and in several other countries (Poland & Jacobson, 2011). The vaccination rate fell to 70% in the United Kingdom after the announcement of Wakefield's study, with rates as low as 50% in some areas that used

to be around 90% previously. Measles began to reemerge in communities with low vaccination rates, and doctors tried to reassure the population that the MMR vaccination was safe, but did not succeed (Goldberg, 2010).

In the original paper, Wakefield and his twelve co-authors claimed to have investigated a "consecutive series" of twelve children referred to the Royal Free Hospital and School of Medicine with chronic enterocolitis and regressive developmental disorders. The study reported that the parents of the children associated their loss of acquired skills, including language, with the MMR vaccination. The authors concluded that "possible environmental triggers," or the MMR vaccine, were associated with the onset of both the gastrointestinal problems and the developmental mental regression, or autism (Eggerston, 2010).

In reality, the published research did not support Wakefield's conclusion that the MMR vaccine was linked to autism and other gastrointestinal issues (Davidson, 2018). Six years after the research was published, concerns began to circulate about the conduct and methods of the study. In March of 2004, ten of the paper's thirteen authors, excluding Wakefield, retracted the "interpretation" section, which claimed an association between MMR, enterocolitis, and regressive developmental disorders, or autism (Laurance, 2013). When *The Lancet* asked for more information on the research from the Royal Free Hospital, where Wakefield conducted the study, Professor Humphrey Hodgson, the then vice-dean of the Royal Free and University College School of Medicine, wrote back to the journal, saying "We are entirely satisfied that the investigations performed on children reported in the Lancet paper had been subjected to appropriate and rigorous ethical scrutiny" (Boseley, 2010).

Two years later, in 2006, measles outbreaks occurred across Britain, and the first death in the United Kingdom from measles in fourteen years was reported (Laurance, 2013). The anti-vaxx movement was becoming more and more dangerous as more people began refusing vaccinations due to the fears associated with them. Many scientists and medical doctors were still questioning Wakefield's research, and the General Medical Council (GMC) opened a case against the study and its authors in July of 2007, alleging serious professional misconduct by Dr. Wakefield and two co-authors of the study (Laurance, 2013). Although Wakefield's research was being accepted by many around the globe, other scientists and researchers were unable to duplicate his findings and questioned his results and methodology (Goldberg, 2010).

It was later discovered by the GMC disciplinary panel that the study was "utterly false," and that children had been subjected to invasive procedures that were not warranted, and that they had undergone lumbar punctures and other tests without ethical approval (Boseley, 2010). In addition to the highly unethical practices used to gather data, Wakefield's sample for his study was extremely small and included only twelve children, making it nearly impossible to determine if a pattern was valid or simply coincidence. When other scientists began to look more closely at the research, they found that most of the children in the study had intestinal issues prior to receiving the MMR vaccine. It was also found that the theory in the study was scientifically implausible for two reasons: first, measles is not correlated with autism, and second, only a small number of children with autism also have gastrointestinal issues, which eliminated the possibility that MMR was a major trigger of autism (Goldberg, 2010).

The General Medical Council also uncovered that the children what were included in Wakefield's study were carefully selected and some of the research was funded by lawyers acting for parents who were involved in lawsuits against vaccine manufacturers. The GMC ultimately found that Wakefield had acted unethically and had shown "callous disregard" for the children in his study, upon whom invasive tests were performed (Eggerston, 2010). On February 2nd, 2010, nearly twelve years after the study was first published, *The Lancet* retracted Wakefield's study following the GMC's decision that Wakefield had been dishonest. *The Lancet's* editor, Richard Horton, stated that "It was utterly clear, without any ambiguity at all, that the statements in the paper were utterly false… I feel I was deceived" (Boseley, 2010).

Although the study was finally retracted and Andrew Wakefield was stripped of his medical license, by the time the scientific community studied and rejected the MMR-autism connection, Wakefield's theory had already been publicized worldwide (Davidson, 2018). Over the twelve years it took to disclaim Wakefield's arguments and mark them as completely invalid, his ideas were fueled by speeches and public appearances in which Wakefield recommended single vaccines rather than the combined MMR, and many parents seeking a cause for their children's illness, such as autism, jumped upon the opportunity to blame it on a routine vaccination. Dr. Suzanne Lewis, a pediatrician and clinical professor of medical genetics at the University of British Columbia in Vancouver, said "I was quite thankful to see the retraction, it's long overdue… why *The Lancet* published it is completely beyond me, the risk-benefit equation was really tipped the wrong way by this research that was so egregious" (Eggerston, 2010). She also mentioned that tens of millions of dollars were spent on

additional studies to validate or disqualify the original Wakefield study (Eggerston, 2010).

This was not the first time Wakefield published a faulty study. In 1993, he blamed measles for Crohn's disease, but his findings were impossible to replicate, leading to his results being killed before even having the chance to be published. His strategy in using a press conference to announce his results in 1998 to announce a said link between vaccinations and autism worked devastatingly well (Goldberg, 2010).

Despite the study being deemed fraudulent, many autism advocacy groups and parents continued to defend Wakefield on websites such as one called Generation Rescue, which was a group founded by actors Jenny McCarthy and Jim Carrey who used their platforms as celebrities to further the idea of a link between vaccines and autism. In addition, the "conspiracy theory" that the manufacturers of vaccines were hiding the truth about the MMR vaccine and autism was fueled by parents wanting an answer to the causes of autism, according to Margaret Spoelstra, executive director of Autism Ontario. Spoelstra mentioned, "We know that autism has a genetic cause and that there are environmental factors that we don't understand yet… there's enormous pressure in the field to come up with those answers" (Eggerston, 2010).

Other Vaccine Fears: Thimerosal and RotaShield

At the same time that the anti-vaxx movement was being fueled by Andrew Wakefield's false study, there were also two other events that added to the vaccine debate, the first being the concerns over thimerosal. When the public became aware that some vaccines contained a preservative called thimerosal, which helps to keep vaccines contaminate-free but also is about 50% mercury be weight, many had concerns. Mercury

in some forms, although not in the form found in thimerosal, is known as a neurotoxin, which is why this issue quickly became connected with Wakefield's claims of the link between vaccines and neurological problems such as autism. Soon, people were claiming that the MMR vaccine caused autism because it contained thimerosal (Davidson, 2018).

Thimerosal had been used without controversy since the 1930s, and it came to the attention of the public after the Food and Drug Administration, with the support of the National Institutes of Health, the Centers for Disease Control and Prevention, the American Academy of Pediatrics, and the American Academy of Family Physicians, sent a letter to vaccine manufacturers requesting that they remove the ingredient from vaccines. Congressional hearings were held on the issue and were covered widely by the press, and by 2001, manufacturers no longer added thimerosal to vaccines in the United States for children under six years of age, except for the influenza vaccine (Davidson, 2018)

After an analysis found that children could get up to 187.5 micrograms of mercury from vaccines in their first six months, concerns were struck among many. However, even after the CDC recommended with the other organizations to take thimerosal out of vaccines, others on the CDC's vaccine advisory committee believed that thimerosal was safe at the levels found in vaccines and that suggesting that it was not would lead to a decline in immunization. At the same time, the European Medicines Agency (EMEA), after a thorough investigation, announced that there was "no evidence of harm to children caused by the level of thimerosal in vaccines currently being used and that it was imperative for vaccination to continue in accordance with national

immunization schedule to prevent disease outbreaks." However, they also mentioned that to ease public concern, thimerosal should be phased out of vaccines (Goldberg, 2010).

By 2002, in the United States, only some flu shots still contained more than a trace amount of thimerosal, even though it had never been proved that there was a link between this ingredient and autism. Nevertheless, during the years following the removal of thimerosal from vaccines, the anti-vaxx movement still persisted, taking a massive online presence and in other forms of media, allowing more and more to question vaccines. Because of this, vaccine rates in some areas in the United States fell below 90-95%, which is what was needed in order to retain herd immunity, which prevents diseases from spreading in a community if they are introduced and protects those who are unable to get vaccinated for medical reasons (Goldberg, 2010).

Anti-vaxxers were not satisfied even after the ingredient thimerosal was removed from vaccines, and they continued to demand proof that vaccines do not cause autism. In 2005, journalist David Kirby published *Evidence of Harm-Mercury in Vaccines and the Autism Epidemic: A Medical Controversy* that kept the vaccine-autism debate in the public eye. It claimed that because scientists were not able to prove definitively at the time that MMR did not cause autism or other harm that it was still possible that it did (Davidson, 2018).

The second incident that sparked concern over vaccine safety after Wakefield's study and the concerns over thimerosal had to do with the RotaShield vaccine. The RotaShield vaccine protects against rotavirus, which is a disease that causes severe and sometimes fatal diarrhea and dehydration in infants. In 1999, the vaccine was voluntarily withdrawn from the market after data suggested that in infants, RotaShield slightly

increased the chance of intussusception, which is a rare condition in which one part of the bowel folds in on itself, causing life-threatening problems if not treated. Although this was extremely rare, anti-vaxx parents claimed that because RotaShield was withdrawn from the market, “big pharma” was pushing harmful vaccines on children and hiding data that showed that vaccines caused damage in the name of profits (Davidson, 2018).

The Truth Between the Correlation of Increased Rates of Autism and Vaccination

The fear that perpetuated the anti-vaxx movement in the late 90s and early 2000s was the fear that vaccines cause autism, when really, they do not. One of the main reasons that many parents believed in this was not just because of Andrew Wakefield’s study, but because an increased number of children in the 90s were being diagnosed with autism. Barbara Loe Fisher stated that before the 1990s, “You didn't see autistic children. Autism was so rare. Most people had never heard of it.” So, because of the increased number of diagnoses at the time, many anti-vaxx parents believed it was because of vaccines (Goldberg, 2010).

However, the truth is that the source of the apparent autism “epidemic” at this time was not due to vaccines at all, but due to the changes in how children were classified and diagnosed with autism spectrum disorders in the 1990s. It was not until 1994 that the criteria for autistic disorders were defined in the DSM-IV along with the criteria for other disorders such as Asperger’s syndrome and other developmental disorders. Some researchers on autism believe that the 50 to 75 percent increase in autism diagnoses at this time were milder cases of the autism spectrum that were finally defined in the DSM-IV. Research has shown that as the criteria changed, so did the diagnoses that children

received, allowing the number of autism diagnoses to increase during this period in correlation with the rise of the modern anti-vaxx movement. The reporting of autism cases also increased at this time due to the educational aid provided by the 1990 Americans with Disabilities Act. Autism became a category for special education in 1991, and the resulting explosion in the number of cases of autistic children in the database is seen because of these things (Goldberg, 2010).

Media and its Influence on Anti-Vaxxers

Despite the fact that Wakefield's study was discredited by reputable scientists, that thimerosal was no longer used in vaccines, and that by the end of 2004, following the Institute of Medicine's report, the link between vaccine and autism was disproved, the idea still continued to gain momentum in the 2000s, especially through media and through endorsements by celebrities, including Jenny McCarthy and Jim Carrey (Goldberg, 2010). McCarthy's son was diagnosed with autism in 2005, and after educating herself with what she termed "the University of Google," she claimed that her "mommy instinct" told her that vaccines had caused her son's autism. She went on a series of live television appearances in 2007, including appearances on *The Oprah Winfrey Show, Larry King Live,* and *Good Morning America.* On these programs that were seen by millions, she blamed vaccines for her son's autism and went on to praise Andrew Wakefield and his work. McCarthy also joined forces with other organizations that blamed vaccines for autism, and her efforts helped to further perpetuate the anti-vaxx movement, especially in the United States (Davidson, 2018).

Unfortunately, because of McCarthy's ability to gain substantial and continued media attention for her anti-vaxx views, thousands of Americans have bought into the anti-vaxx movement and the belief that vaccines caused their children's autism. In addition to the ideas perpetuated by celebrities like McCarthy, following the retraction of *the Lancet* study by Andrew Wakefield, the media gave far less coverage to the truth of the study than they had about the lie that it had originally told. However, over the recent years, there has been a shift in the news media in that many have finally made it clear that research shows no connection between immunizations and autism, and new articles are coming out daily that further expose the lies that many anti-vaxxers believe. The problem now isn't with the news media perpetuating false information, but with social media and the information that is spread by anti-vaxxers on those sites daily (Goldberg, 2010).

The Modern Anti-Vaxx Movement

Today, the anti-vaxx movement is prospering as access to medical information online has dramatically changed the dynamics of healthcare knowledge. Medical knowledge that was previously only found in textbooks and journals can now be found online and is accessible to the layman, which had allowed shared decision-making between patients and healthcare physicians to flourish. However, while this has been beneficial, it also has led to the dissemination of false and misleading information regarding vaccines that can be found on the internet, which can lead to negative consequences such as parents not giving consent to having their children vaccinated. False information regarding vaccines is plentiful and easy to find on the internet (A. Hussain et al., 2018).

A 2018 article entitled *The Anti-vaccination Movement: A Regression in Modern Medicine* by Azhar Hussain, Syed Ali, Madiha Ahmen, and Sheharyar Hussain cited several analyses and studies regarding social media and the perception of vaccines online. The first was an analysis of YouTube videos about immunization that found that 32% opposed vaccination and that these videos that opposed had higher ratings and more views than pro-vaccine videos. A similar analysis of MySpace blogs regarding HPV immunization found that 43% were negative and that most of these blogs cited inaccurate data. Another analysis of Canadian internet users tracked the sharing of influenza vaccine information on sites such as Facebook, Twitter, and YouTube and of the top search results during the study period, 60% promoted anti-vaccination sentiments. The fourth study examined the content of the first one-hundred anti-vaccination sites found after searching "vaccination" and "immunization" on Google, and it concluded that 43% of websites had anti-vaxx views, including all of the first ten listed (A. Hussain et al., 2018).

Online anti-vaxxers skew science, shift hypotheses, censor opposition, attack critics, claim to be "pro-safe vaccines" and not "anti-vaccine" and claim that vaccines are toxic and unnatural among several other reasons in their objective to forward their agenda. These tactics are not only deceitful and dishonest, but also have caused a decrease of vaccination rates in the United States as parents believe their messages online. Azhar Hussain, Syed Ali, Madiha Ahmen, and Sheharyar Hussain in their 2018 article also reported on a study that evaluated how effectively users assessed the accuracy of medical information about vaccines online and concluded that 59% of student participants thought the sites were entirely accurate. However, out of the 40 sites they were given, only 18 were entirely accurate, and the other 22 were inaccurate. The

inaccurate sites presented in the study were not evidence-based and argued that vaccines were inherently dangerous without any merit-based argument, and 53% of participants led the exercise with misconceptions about vaccines. The 2018 article also reported that research has shown that viewing an anti-vaxx website for five to ten minutes increased perceptions of vaccinations' risks and decreased perceptions of the risks of vaccine omission, and that the anti-vaxx sentiments obtained from viewing the websites still persisted five months later, causing the children of these parents to get fewer vaccines than recommended by medical professionals (A. Hussain et al., 2018). Online media, especially social media, has played a major role in perpetuating the anti-vaxx movement in the twenty-first century, and because of it, our country is still threatened by vaccine-preventable diseases every day.

The Current State of Vaccination

According to the National Center for Health Statistics (2017), the percent of children aged 19-35 months receiving vaccinations for vaccine-preventable diseases in 2017 are as follows: Diphtheria, Tetanus, Pertussis (DTaP), 83.4%; Polio: 91.9%; Measles, Mumps, Rubella (MMR), 91.1%; *Haemophilus influenzae* type b (Hib), 81.8%; Hepatitis B, 90.5%; Chickenpox (Varicella), 90.6%; Pneumococcal conjugate vaccine (PCV), 81.8%; and combined 7-vaccine series, 70.7% . **Tables 4a, 4b, 4c and 4d** show the vaccination coverage for selected disease among children aged 19-35 months, by race, Hispanic origin, poverty level, and location of residence in metropolitan statistical area in United States for the selected years between 1998 and 2016, compiled by the CDC in 2017. These tables show how although vaccination rates have increased for the

most part since 1998, these numbers have fluctuated over the years and for the most part have decreased in 2016, influencing how our nation is protected from infectious disease.

A drop in immunization poses a threat to the herd immunity, or the protection of communities from infectious diseases by vaccinating a vast majority of its members, that the medical profession had worked hard to achieve over the years. It takes around 90-95% of a community to be vaccinated for herd immunity to work in protecting those unvaccinated individuals who cannot be vaccinated due to medical reasons. The only thing that can protect populations against a rapidly spreading disease is the herd immunity created when the majority of a population are immune thanks to vaccinations (A. Hussain et al., 2018).

Over the past five years, outbreaks of infectious disease in the United States has influenced policies in states and has caused the general public to rethink the importance of vaccines. Dr. Amanda Cohn, senior advisor for vaccines for the CDC's National Center for Immunization and Respiratory Diseases mentioned that the "strong recommendation for children… to get vaccinated is incredibly influential on a parents' choice to get vaccinated...reiterating the importance of vaccination and helping parents understand the benefits of vaccination and the severity of diseases they are preventing is really important" (Jenco, 2018). The World Health Organization had listed vaccine hesitancy, or the reluctance or refusal to vaccinate despite the availability of vaccines, as a top ten threat to global health in 2019 (World Health Organization, 2019). Our current state of vaccination is one that needs to be drastically changed in order to keep our nation free from the threat of infectious disease.

2015 Measles Outbreak in Disneyland

On January 3rd, 2015, the California Department of Public Health received a call about a suspected measles case in an unvaccinated 11-year-old boy who recently visited Disneyland. Two days later, six additional suspected measles cases were reported, two from Utah and four from California, and all patients had recently traveled to Disneyland. The California Department of Public Health alerted the CDC and the other local health jurisdictions in California, but the damage was already done, and the measles outbreak was spreading. The measles case originated from one infected child at Disneyland on December 27th, 2014 and spread nationally and internationally to infect 131 total people located in Arizona, Utah, Nebraska, Washington, Colorado, Oregon, Mexico, and Canada (Harriman, 2015).

Of the 131 total cases, 42 were exposed to measles at Disneyland, 31 were exposed in their household or by other close contact to an infected person, 11 were exposed in a healthcare setting, 3 were healthcare personnel, 3 were exposed in a shopping mall, and 44 had an unknown exposure setting. 82 of the 131 total cases had their immunization statuses verified, and of the 82 cases, 70%, or 57 people, were unvaccinated. When probed as to why they were unvaccinated, 49% said because of personal beliefs, 28% were too young to receive the vaccine, 4% missed the dose, and the other 19% had unknown reasons. Only 25 people, or 31% of the 82 cases were vaccinated. The other 49 of the 131 total cases did not have immunization records (Harriman, 2015).

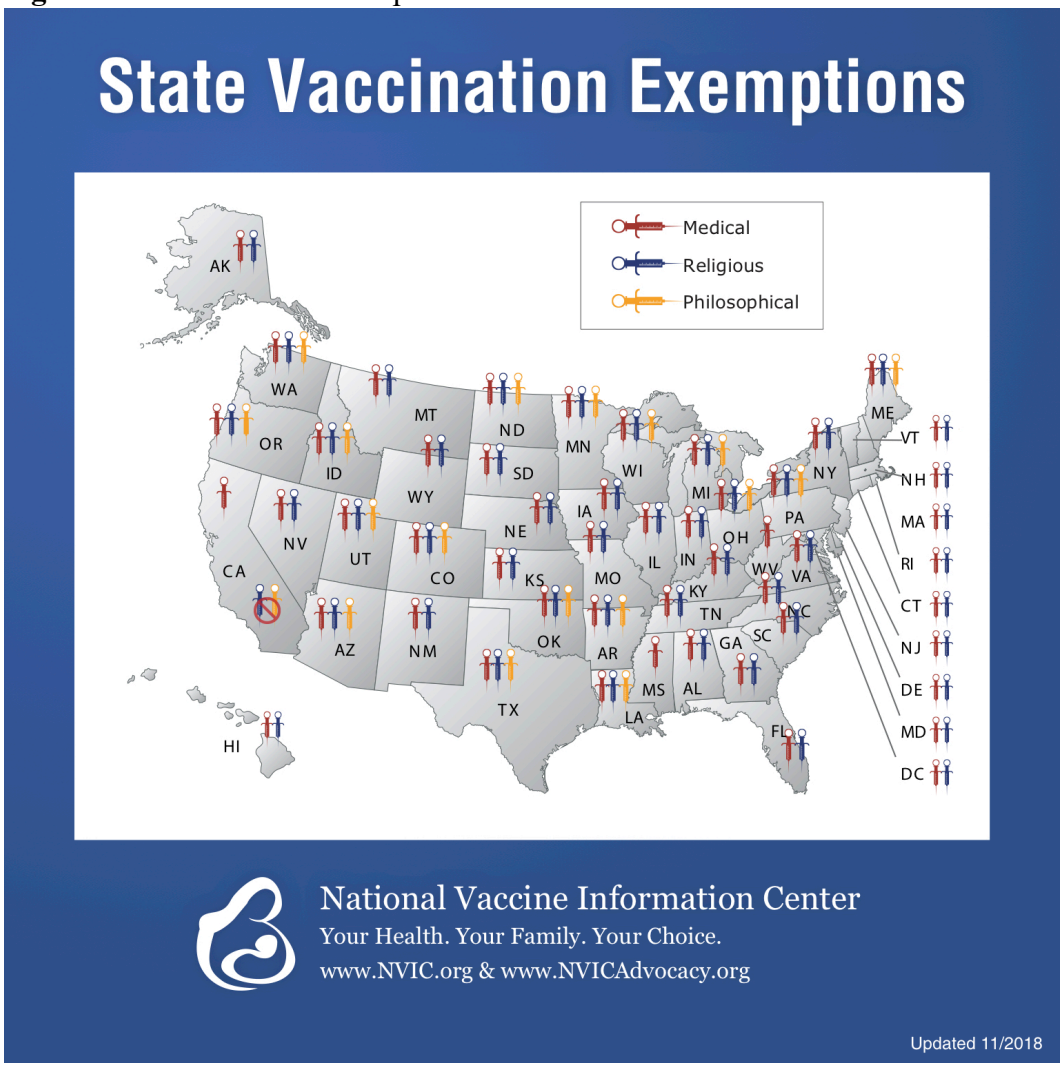
On June 30th, 2015, a few months after the outbreak, California Governor Jerry Brown signed SB 277 into law, eliminating personal and religious vaccine exemptions

for children to attend daycare, preschool, and K-12 schools in California (California Department of Public Health, 2015). Because of this, California has some of the strictest compulsory vaccine laws in the country.

Current State Compulsory Vaccine Laws

States have different laws regarding vaccines, and some are much stricter than others. The three states with the strictest compulsory vaccination laws in the United States include West Virginia, Mississippi and most recently California. Who would have thought that two of the states with some of the worst health rankings would have the strictest vaccine laws? West Virginia has maintained strong vaccination policies for decades and is the only state that has never had non-medical exemptions, keeping the state free of any measles outbreaks for decades. The state of Mississippi followed West Virginia's lead in 1979, when its Supreme Court found the state's religious exemptions to be unconstitutional, citing a previous ruling of *Prince v. Commonwealth of Massachusetts* that determined "the right to practice religion freely does not include liberty to expose the community or the child to communicable disease or the latter to ill health or death." Because of Mississippi's laws, the State has not had a measles outbreak since 1992 (Moon, 2019). **Figure 1**, provided by the National Vaccine Information Center (2018), shows the exemptions allowed in each state:

Figure 1: State Vaccine Exemptions



All 50 states allow medical exemptions to vaccination, which means that immunocompromised people or people that are allergic to certain vaccinations are not required to get them. Forty-seven states, not including Mississippi, West Virginia, and California, allow for either religious or personal belief exemptions, and some states allow both. However, each state has their own laws dictating how difficult it is to obtain an exemption. States that have easier exemption policies, such as those in Colorado, have ongoing problems with outbreaks of disease (Marcus, 2017).

Current Events: Vaccination in the News in 2019

From January 1st to April 11th, 2019, there have been 555 cases of measles confirmed in twenty states across the United States, representing the second-greatest number of cases reported in the U.S. since measles was eliminated in 2000. This number is continuing to grow every day, and the states that have reported cases to the CDC include Arizona, California, Colorado, Connecticut, Florida, Georgia, Illinois, Indiana, Kentucky, Maryland, Massachusetts, Michigan, Missouri, Nevada, New Hampshire, New Jersey, New York, Oregon, Texas and Washington. Of these fifteen states, six outbreaks are currently ongoing in 2019 in four states: New York, Washington, California, and New Jersey. All of these outbreaks have been linked to travelers who brought measles back from other countries such as Israel, Ukraine, and the Philippines (CDC, 2019).

Williamsburg, Brooklyn, New York

On April 9th, 2019, the New York City Department of Health and Mental Hygiene commissioner, Oxiris Barbot, ordered that

> Any person who lives, works, or resides within the 11205, 11206, 11211, and/or 11249 zip codes and who has not received the MMR vaccine within forty-eight (48) hours of this Order being signed by me shall be vaccinated against measles unless such person can demonstrate immunity to the disease or document to the satisfaction of the Department that he or she should be medically exempt from this requirement. (Barbot, 2019).

This order was in response to the ongoing measles outbreak in the area that has seen over 250 cases and is still growing. Barbot cited that his reasoning for the Order is to stay consistent with the New York Health Code that states that no person "shall do or assist in

any act which is or may be detrimental to the public health or to the life or health of any individual…". Failure to comply with this Order results in a violation of the New York City Health Code and is a misdemeanor, which can result in fines and potentially imprisonment. (Barbot, 2019).

Rockland County, New York

The current outbreak in New York is located in Rockland County, and as of April 3rd, 2019, there were 161 confirmed cases of measles. Of these 161 cases, 83.2% of the people were unvaccinated (County of Rockland, 2019). In response to the growing measles outbreak, Rockland County officials have declared a state of emergency had have placed a 30-day ban on any unvaccinated individuals under the age of 18 from being in public places. By declaring this state of emergency, officials hope that parents will realize how serious the problem of vaccine hesitancy brings to communities and hopes that parents will rethink their decision not to vaccinate their children. Rockland County Executive Ed Day declared "I must take this step to protect the infants, infirm, and ill of this County who are unable to be vaccinated against the measles or who are immunocompromised... I must make every effort to protect them" (Schwartz, 2019).

Brooklyn and Queens, New York City

As of April 3rd, 2019, there was 259 confirmed cases of measles in Brooklyn and Queens, most involving members of the Orthodox Jewish community. The disease was initially brought to the neighborhoods of Brooklyn and Queens from an unvaccinated child who acquired measles on a visit to Israel (City of New York, 2019). This is around

the same area as Williamsburg where there has also been a large outbreak as mentioned above.

Washington State

As of March 22nd, 2019, there were 74 confirmed cases of measles in Clark and King counties in Washington State (Washington State Department of Health, 2019).

New Jersey

As of April 3rd, 2019, there were 11 confirmed cases of measles. There were 9 outbreak-associated cases including 7 in Ocean County residents and 2 in Monmouth County residents and of these cases, individuals could have been potentially exposed to the infection in New Jersey between March 9th and March 14th (State of New Jersey, 2019).

California

As of March 27th, 2019, 16 confirmed measles cases, including 11 outbreak-associated cases, were reported (California Department of Public Health, 2019).

Of all of these current outbreaks of measles in the United States, a majority of cases are due to unvaccinated individuals. As unvaccinated travelers continue to acquire diseases and bring them back to the United States, our public's health is put at risk, especially those who cannot receive vaccinations due to medical reasons (CDC, 2019). In addition to these cases of measles threatening the health and safety of Americans, the low rates of vaccination of other infectious diseases have left populations vulnerable and have

cost our health care sector hundreds of thousands of dollars, as seen with a recent case of tetanus in an unvaccinated child in Washington state.

There is hope, however, that our vaccination rates will begin to increase after the link between autism and the MMR vaccine was completely debunked by a large study that was published on March 5th, 2019. Although this has been proven before in years prior, this study is extremely significant because it contained over 600,000 participants, the largest sample of any study of its kind, further adding fuel to the fire in the argument against the link between vaccines and autism. The study, published by the Annals of Internal Medicine with authors Anders Hviid, Jorgen Vinslov Hansen, Morten Frisch, and Mads Melbye, is entitled *Measles, Mumps and Rubella Vaccination and Autism: A Nationwide Cohort Study*. It was done in Denmark and began in 1999 and ended in 2010, with follow-ups through 2013 (Hviid, Hansen, Frisch & Melbye, 2019).

The study used Danish population registries to link information on MMR vaccination, autism diagnoses, other childhood vaccines, sibling history of autism, and autism risk factors to children in the cohort, which included 657,461 children total. Of the 657,461 children in the study, 6,517 were diagnosed with autism, which is an incidence rate of 129.7/100,000 people. The study presented evidence that strongly supports that MMR vaccination does not increase the risk for autism, does not trigger autism in susceptible children, and is not associated with clustering of autism cases after vaccination, further proving that there is no link between the MMR vaccine and autism (Hviid et al., 2019). This study once again disproving the link between vaccines and autism comes nearly twenty years after Andrew Wakefield's bogus study, and yet, the anti-vaxx movement is still alive and well in today's society.

Current Resistance

The World Health Organization has listed vaccine hesitancy as one of the top threats to global health in 2019. In its publication, *The State of Vaccine Confidence*, the SAGE working group defines vaccine hesitancy as

> A behavior influenced by a number of factors including issues of confidence, complacency, and convenience. Vaccine-hesitant individuals are a heterogeneous group who hold varying degrees of indecision about specific vaccinations or vaccines in general. Vaccine-hesitant individuals may accept all vaccines but remained concerned about vaccines; some may refuse or delay some vaccines but accept others; some individuals may refuse all vaccines. (Feemster, 2018).

Vaccination is one of the most cost-effective ways of avoiding disease and it currently prevents two to three million deaths a year and could potentially avoid 1.5 million more deaths if global coverage of vaccinations was improved. Reasons why people choose to not vaccinate are complex and range from complacency, inconvenience in accessing vaccines, and lack of confidence in vaccines (World Health Organization, 2019).

Fear of disease has wreaked havoc on our planet throughout the years, and even today it remains a concern among many as more and more people are becoming infected with vaccine-preventable diseases. Vaccination has made such an enormous impact on global health and has eradicated horrendous diseases; however, there is an increasing number of people opposing vaccination even in today's society for a number of reasons, as cited by the World Health Organization. These reasons include the belief that vaccines cause autism, that the ingredients in vaccines cause harmful side effects, that diseases have been virtually eliminated from the world, so there is no need to vaccinate and that

giving a child multiple vaccinations at the same time increases the risk of harmful side effects and overloads the immune system (World Health Organization, 2018). Changing the opinions of anti-vaxxers is not as easy as it may seem, and because of this, other measures must be taken in order to increase vaccination rates in our country, and that is where policy steps in.

Chapter 5

Recommendations

Childhood vaccination has proven to be one of the most effective public health strategies to control and prevent disease, yet some parents do not vaccinate their children because of medical, religious, philosophical, or socioeconomic reasons. As our immunization rates continue to stray away from the percentage required to maintain herd immunity, more and more vaccine-preventable diseases are emerging in the United States due to the refusal to vaccinate, incomplete vaccination series, waning immunity, and imported cases of disease. Many misconceptions about vaccines exist, and because of this, the public is often misinformed about the importance of vaccines on public health (Ventola, 2016).

Using Instruments of Public Policy to Increase Vaccination Rates

In order to increase our country's immunization rates, there are several policy recommendations and government interventions that can be made. The instruments of public policy that can be used include the use of regulation, government management, education, information, and persuasion, and market mechanisms. Governments can also regulate, use market incentives, educate, and conduct research to improve immunization rates. Along with these instruments of public policy, it is also important to evaluate the criteria for public policy proposals in order to determine its effectiveness, efficiency,

equity, liberty, political feasibility, administrative feasibility, and technical feasibility. A combination of these, or all of them, can be used to increase the immunization rates in the United States, and directions that can be taken to do so will be discussed and recommended in detail in this section by the author.

Compulsory Vaccine Laws at the State Level

The first policy tool that can be used to increase vaccination rates in the United States include the use of regulation, or laws enacted by state or even federal legislatures that require vaccination. As mentioned previously, vaccination is compulsory for school-aged children in the United States, but there are exemptions for religious, medical and philosophical reasons. Public health officials have become increasingly worried about the option for parents to claim exemptions from vaccination requirements, and because of several recent outbreaks of vaccine-preventable diseases, more attention has been brought to these exemptions, causing many states to rethink their vaccine laws (Ventola, 2016).

Currently, medical exemptions, which are exemptions for immunocompromised individuals or people who cannot receive vaccines for medical reasons, are accepted in all states. Herd immunity is important in protecting these people who are medically unable to get vaccinated, and this exemption is the one that stands apart from the rest in that it is a legitimate medical and health safety reason to not be able to receive a vaccine. Forty-seven states allow religious exemptions to vaccines and another twenty offer exemptions for philosophical reasons. It has been estimated that one to three percent of children are excused from immunization because of these exemptions, but in some communities, the exemption rate is as high as twenty percent, increasing the risk of disease outbreaks (Ventola, 2016).

As mentioned previously, there are three states that do not allow religious or philosophical exemptions: Mississippi, West Virginia and California. These states have had some of the highest immunization rates in the country because of their strict compulsory vaccination policies, showing that regulating vaccine laws through the states is an effective measure in increasing immunization rates. Promoting best practices at the state level is one strategy to improving vaccine coverage rates, and there is a growing body of evidence showing the impact that state vaccination requirements for school aged children has on vaccination coverage and the association of non-medical exemption rates with increased disease incidence (Centers for Disease Control and Prevention, 2015).

Recent findings that support the fact that stricter vaccination laws lead to better immunization rates and less outbreak of disease include that the use of philosophical exemptions tend to cluster geographically, making some communities greater for risk of outbreaks, including immigrant communities specifically. In addition, the geographic clustering of exemptions is associated with increased local risk of vaccine-preventable diseases such as pertussis and measles, which are both highly contagious. The CDC's Public Health Law Program compiled state statutes and regulations regarding school vaccinations and has concluded that states have successfully implemented these compulsory laws by requiring proof of vaccination for school entry, applying their immunization requirements to both public and private school, and establishing vaccination requirements for children in day care (Centers for Disease Control and Prevention, 2015).

Vaccine mandates and laws in states have had a positive impact on overall vaccination rates and are a solution to increasing vaccine rates in the United States.

However, gaps still exist in several states, and they need to be fixed in order for our general public to be free from the threat of infectious disease. As seen from Mississippi, West Virginia and California, compulsory vaccine laws are effective in preventing infectious disease and lead to higher immunization rates, however, there are some limitations that exist in implementing these laws in every state. Political feasibility and social acceptability are a challenge because there are many that still are hesitant about vaccines and therefore, it may be hard to pass in every state. However, a solution to this would be to further education that disproves the fears that many have about vaccines and to promote the benefits that a vaccinated population brings to a community through education.

Administratively and technologically wise, these laws are extremely feasible to be implemented in states as several states have already done. In addition, the argument of a person's individual rights also come into play, but as seen with several supreme court cases, maintaining the public's health outweighs one's decision to get vaccinated or not, so these laws are necessarily in protecting our country's citizens. Unfortunately, it may take a disease outbreak disaster like the one seen in California in 2015 to get more states to follow suit and implement stricter vaccine laws, but once all states have compulsory vaccine laws that only allow for medical exemptions, it can be assumed that the rate of disease outbreaks will decrease as the immunization rate increases.

Compulsory Vaccine Laws at the Federal Level

Currently, all compulsory vaccine laws are left up to the states to decide on and enact. However, as more disease outbreaks have happened and the rate of immunization has decreased over the years, people have started to question the role of the federal

government in protecting its citizens through the creation of federally-mandated compulsory vaccine laws. In fact, on February 21st, 2019, the Food and Drug Administration's Commissioner, Dr. Scott Gottlieb, said the federal government might someday need to begin regulating vaccine policies if "lax" state vaccine laws continue to allow the resurgence of vaccine-preventable diseases to occur. Gottlieb also said that the widespread exemptions allowed by states are "creating the opportunity for outbreaks on a scale that is going to have national implications" and could "force the hand of the federal health agencies" in order to attempt to control the continued disease outbreaks (Ducharme, 2019).

Although there have been no actual steps toward implementing federal compulsory vaccine laws, Gottlieb's comments bring up many good points in the battle against infectious diseases and the obligation that the government has to protect the health of its citizens. Medical groups such as the American Medical Association (AMA), the American Academy of Family Physicians, and the American Academy of Pediatrics have opposed vaccine exemptions for years, except for medical exemptions. In a 2015 release from the AMA, board member Dr. Patrice Harris stated that, "protecting community health in today's mobile society requires that policymakers not permit individuals from opting out of immunization solely as a matter of personal preference or convenience" as many religious and philosophical exemptions have become more common (Ducharme, 2019).

When comparing to state compulsory vaccine laws, federal laws also reach political and social acceptability barriers, but also, it faces some administrative feasibility issues as policies like this have never been enforced on the federal level. A policy like

this would be effective and efficient at increasing vaccine rates in the United States, but it would have a much harder time in garnering support because many support the idea of federalism, or the separation of the state and federal government, and believe that vaccine laws should be left up to the states. However, if states do not reconsider their current vaccine laws that allow for numerous exemptions, the federal government may have to intervene in order to protect the citizens of the United States from the threat of infectious disease.

Health Care Provider-Based Interventions

Another policy tool that can be used to increase vaccination rates is increasing education, information, and persuasion and also using government management and market mechanisms to get more people vaccinated. The CDC's Task Force on Community Prevention Services identifies three categories for interventions to overcome vaccine noncompliance: increasing community demand for vaccination, enhancing access to vaccination services, and provider-based interventions. There are several health care provider-based interventions that can be made to overcome vaccine noncompliance that include patient counseling, improving access to vaccines, maximizing patient office visits, offering combination vaccines, and using electronic medical records and practice alerts to better identify a patient's vaccine schedule (Ventola, 2016).

Patient Counseling

Studies have consistently shown that absent or weak recommendations from health care providers have led to decreased vaccine rates. So, it is important to develop interventions that target health care providers and their practices so that they may be the

primary educators for parents who may question the safety or necessity of vaccines. The first intervention is patient counseling, or patient education. Studies have found that the most important factor influencing parental decisions about vaccinations is communication with the health care provider, so parental and patient education provided by primary care physicians, or the physician giving the vaccine, is especially important in increasing vaccine rates. Most parents are not familiar with vaccines or have been improperly informed about them due to lies spread on social media, so educating them in the healthcare setting that vaccines are indeed safe and effective is the most important part in increasing vaccine compliance (Ventola, 2016).

With the intervention of providing parent and patient counseling, providing training and materials to providers who may encounter vaccine-hesitant patients is also important. Research has focused on training healthcare providers to use proven communication strategies when vaccine hesitancy is encountered while also discussing the research concerning safety concerns about immunizations with parents. The health care provider's office should also provide parents with information about upcoming immunizations before a child's scheduled visit so that they can gain an understanding of any recommended vaccinations. Parents should also be provided with a vaccination record that summarizes all of their child's past immunizations and the recommended dates for future immunizations. Patient-reminders are also important because keeping with the vaccine schedule ensures that a child is as protected as they can be from infectious diseases (Ventola, 2016). A summary of these interventions is included in **Table 5** in the appendix.

In addition to this intervention, the National Foundation for Infectious Diseases (2016) also addresses how vaccine rates can be increased through ongoing communication with parents and adolescents about vaccines. It is essential that parents and adolescents have the correct information from health care providers regarding vaccines and not information from social media that often is laced with misinformation. This intervention is politically, socially, administratively, and technologically feasible in that most people agree that providing more information to patients is a good thing. However, an obstacle may be reached when determining how to administer this information in a standardized way as not all health care practices are the same and use the same methods. Either way, this intervention is an effective one that can be done with little costs while having a large impact.

Maximizing Opportunities During Patient Visits

The second intervention that can be made by health providers to improve vaccination compliance is maximizing opportunities during patient visits. In the U.S., around two-thirds of under-vaccination in children younger than two years of age has been due to missed opportunities that have led to missed visits and failure to provide needed immunizations at every opportunity that contributes to complete vaccination requirements. After age two, most children are only brought to the doctor when they are sick. However, they need to be brought in much more frequently to get the vaccines that are needed according to the vaccine schedule. Because of this, all clinical encounters, including visits for injuries or mild illness, should be considered as an opportunity to administer needed vaccines. In addition, in order to get more children vaccinated when they come to see a healthcare professional, a standing order for the vaccination of

patients should be issued to allow nurses to do so independently of physicians. Nurses should routinely verify a patent's vaccination status and offer to administer any other needed vaccines (Ventola, 2016). A summary of this intervention is included in **Table 5** in the appendix.

The National Foundation for Infectious Diseases (2016) also recommends that during patient visits, all health care providers should be involved in vaccine delivery. While school-based vaccine delivery is not routine, vaccine recommendations and reminders from school nurses can be very valuable. So, expanding support to all healthcare providers and ensuring that their messages to patients about the importance of vaccines are all positive can make a difference. This intervention is politically, socially, administratively, and technologically feasible because many believe that every corner should be accounted for at a doctor's visit, so minimizing wasted time and resources and instead giving more vaccines and ensuring that the schedule is being followed is a good thing. Like educating patients on the important of vaccination, this intervention is an effective one that can be done with little costs while having a large impact.

Administering Combination Vaccines

The third intervention that can be made by health providers to improve vaccination compliance is through administering more combination vaccinations. The simultaneous administration of childhood vaccinations through combination vaccines such as the MMR and DTaP vaccines have been deemed both safe and effective and avoid the need for as many return visits. It has also been observed that when the advantages of combination vaccines are explained to patients and parents, adherence is improved (Ventola, 2016). So, anything that can be done to increase the use and creation

of combination vaccines in healthcare can help increase immunization rates as well. A summary of this intervention is included in **Table 5** in the appendix.

This intervention may have a harder time being politically and socially feasible because many parents worry that combination vaccines can overload the immune system and are not safe. However, through education, these individuals can learn from their healthcare providers that they are indeed safe and are effective at preventing illness. Additionally, there are setbacks in administrative and technological feasibility because there are only a few vaccines that are offered in combination, so if more were to be created, they would have to go through the process of rigorous testing and approval to get there, which takes time. However, with the combined vaccines we already have, this intervention is doable and is effective and efficient in preventing disease.

Improving Access to Vaccinations

The fourth intervention that can be made by health providers to improve vaccination compliance is by improving access to vaccinations. Individuals in disadvantaged socioeconomic groups encounter many obstacles that can interfere with getting vaccinations according to the vaccine scheduled, affecting compliance. Circumstances such as job responsibilities, not being able to keep up with appointments, unreliable transportation, relocating frequently, or having other difficult circumstances can affect the opportunity of staying on the vaccine schedule. Making vaccinations easier to obtain for people who fall in this group is the most effective intervention in increasing vaccination rates. This can be done by allowing patients to be seen on the same day that they call to make an appointment via walk-in appointments and having a supportive staff

and convenient office with limited wait times also helps with this (Ventola, 2016). A summary of this intervention is included in **Table 5** in the appendix.

There are so many other ways in which vaccinations can be delivered to low socioeconomic communities, but they differ from community to community based off of what services they can offer for their citizens. In-school vaccination centers may be the best way to combat this issue, but again, it comes down to the policies that are in place in each state in whether this is a feasible solution. However, making it easier for people to receive vaccines through greater accessibility is necessary to increase the vaccination rate in our country. This is politically and socially feasible because most agree that improving access to health services such as vaccination is a good thing. However, administratively, it does come at a cost to improve access, but if the benefits outweigh the costs, then it is a smart move to provide better access to vaccines and it would be an effective and efficient way to increase compliance.

Using Electronic Medical Records and Practice Alerts

The fifth intervention that can be made by health providers to improve vaccination compliance is through the use of electronic medical records (EMRs) and practice alerts. Computerized tracking of patient records across health care has improved communication in the healthcare setting and is the ideal avenue for reducing vaccine errors and missed opportunities for vaccination. Most health care systems now utilize EMRs, and data has shown that practices with these systems in place have increased immunization rates, which is why all health care practices should switch to electronic patient management in order to allow vaccination rates to increase further in our nation. These EMRs also improve efficiency and accuracy by standardizing record-keeping

regarding vaccinations and missed visits, so that healthcare professionals can use the system to identify patients who are not up to date with their immunizations and can send them a notice (Ventola, 2016). A summary of this intervention is included in **Table 5** in the appendix.

The National Foundation for Infectious Diseases (2016) also recommends this same intervention is that one of the most effective tools in increasing vaccination rates is a standing order, which allows the administration of vaccines who all patients who meet certain criteria in the EMR system. The system also provides reminders to patients when vaccinations are due so that they can make an appointment. This intervention is politically, socially, and administratively feasible in that these systems already exist and anything that makes the process of standardizing medical records is effective and efficient and increases benefits while decreasing costs. However, not all practices have this type of technology, so some do not have the technical feasibility to implement this type of intervention yet.

Community and Government-Based Interventions

In addition to health care provider-based interventions, there are also community and government-based interventions that aim to enhance vaccination rates. They include increasing outreach and educational programs, using recall and reminder strategies, providing financial incentives, and offering vaccination at nontraditional sites (Ventola, 2016).

Public Education

It has been shown that parent-driven or patient-based education coupled with community or government-based measures can improve immunization rates. Rather than relying solely on patient/parent education, using newer educational methods that incorporate community input and web-based tools for information dissemination can be effective. Examples include educational brochures and other brief public messaging interventions directed at parents and adolescents. It is also important to evaluate the effect of different messaging strategies on intention and vaccine receipt when the messages are delivered in a setting where vaccinations can be administered. Without awareness, many do not know the truth and importance of vaccination (Ventola, 2016). A summary of this intervention is included in **Table 6** in the appendix.

Similar to patient and parent counseling, this intervention is politically, socially, administratively, and technologically feasible in that most agree that providing more information to the general public is a good thing. However, an obstacle may be reached when determining how to administer this information in a standardized way and in an efficient and effective way to the general public. Either way, this intervention is an effective one that can be done with potentially little costs if done digitally while having a large impact.

Public Reminder and Recall Strategies

As discussed previously, parent and clinician reminders regarding upcoming vaccinations and recalls for vaccinations that are past due is another evidence-based approach for improving vaccination rates. These can be done by mail or by phone and are instituted at the individual practice level, so it can differ from practice to practice, city to

city and state to state. However, if it can be standardized among most practices, it can make a huge difference in reminding people to get their vaccinations according to the vaccine schedule. With the advances in technology and in the EMR system, this process can potentially be centralized so that a coordinating agency, possibly a health department, can implement it. Advancements in electronic communications have been essential in the rapid sharing of health and safety information and these communications have allowed for real-time health updates and the broad sharing of information that has enhanced public health partnerships. With the increased use of mobile phones for health-related activities, the impact of a reminder or recall message is something that needs to be examined as it can greatly increase the vaccination rates in our country (Ventola, 2016). A summary of this intervention is included in **Table 6** in the appendix.

Politically, socially, and administratively, this intervention can be done of the system in place is able to send these reminders and recalls, because most agree that reminders and recalls are beneficial in keeping patients in the loop and up to date in regard to their health. However, technical feasibility is hard when some practices do not have the technology to send these sorts of reminders electronically, but they can also be sent via mail and by a phone call. So, it may not be standardized across all boards, but it will still be effective and efficient in reminding people to get their vaccines according to the vaccine schedule.

Free Vaccines and Other Financial Incentives

Another intervention that communities and governments can use to increase vaccination rates is by issuing financial incentives to parents or patients, such as an entry into a lottery for a gift or providing free vaccines for free to the uninsured. This is

especially beneficial for people who may not have health insurance or cannot afford to see a doctor (Ventola, 2016). A summary of this intervention is included in **Table 6** in the appendix.

This intervention comes with more problems with political, social, and administrative feasibility because it does cost money to offer free vaccines and other financial incentives for them, so not everyone may approve of this sort of policy because it costs money. However, if the benefits of this intervention outweigh the costs, then they may be more likely to accept it. Also, many may agree with the policy because they otherwise would not be able to afford visiting a doctor or may not have insurance, so they would accept this intervention. Overall, if the benefits outweighed the costs, it could be an effective and efficient intervention.

Alternative Public and Private Venues for Vaccination

The last community and government-based intervention to improve vaccine compliance is the use of alternative venues for vaccination. Many studies have provided evidence supporting school and daycare-based vaccination programs and improvement in vaccination rates has also been seen by opening walk-in vaccination clinics run by nurse practitioners on evenings and weekends for people who cannot make it to the doctor's office during the day. Offering vaccinations at pharmacies that have convenient hours has also proved beneficial. Other possible alternative immunization venues include emergency departments, Women, Infants and Children (WIC) program offices, impatient settings, and home visits (Ventola, 2016). A summary of this intervention is included in **Table 6** in the appendix.

This intervention could be politically and socially feasible because it provides immunizations to those who cannot visit the normal hours of a healthcare facility due to work or other responsibilities during the week. So, this intervention would increase access, which most agree with. However, administratively and technologically, getting these alternative venues for vaccination is not always easy, but when it is able to be done, it is an effective and efficient intervention to increase the vaccination rates in the nation.

Discussion

Vaccines to prevent infectious diseases were created for a reason, and their ability to protect and save lives from disease can only be successful when parents and patients comply with health officials and health care providers and get the recommended vaccines according to the vaccine schedule. Because of the perpetuation of the anti-vaxx movement and the continued hesitancy and resistance toward vaccines in our country, interventions by state governments, the federal government, health care providers, and community and government-based organizations are needed so that vaccine coverage can be increased in our nation. If policy interventions are not made soon, infectious diseases that once were virtually invisible because of the success of vaccination will continue to spread at a dangerous rate across our nation, putting the health and safety of our citizens at risk.

Chapter 6

Conclusions

Vaccines have proven successful in preventing infectious disease for years and have even allowed for the eradication of smallpox in the twentieth century. However, the growing number of people refusing to vaccinate has caused vaccine-preventable infectious diseases to continue to flourish in our modern world, putting the public's health at risk. Vaccine hesitancy is not a new concept, as people have questioned the medical profession since the before the birth of our nation. Time and time again, medical science has proven the safety and effectiveness of vaccines, yet, many still resist this solution to infectious disease. Now, it is up to policy interventions through the states, the federal government, health care providers, and community and government-based organizations to increase the vaccination rate in our country through measures intended to increase vaccine compliance.

Limitations

There were a few limitations to the author's research strategy. Because the author conducted a literature review and collected secondary information only, the author did not collect primary research. In order to have collected primary information, the author would have had to go out into the community and conduct interviews and distribute surveys in order to collect data for primary information. This primary information could

have helped the author in determining attitudes toward vaccination in different communities and why there is resistance in these communities. Additionally, this information could have helped the author determine how individuals learned about vaccination and how much they know about the vaccination, which could aid the author in determining the best way to educate the public on the importance of vaccines for the recommendations section.

In addition to the limitations surrounding the author's decision to do a literature review and collect secondary information only, there are also limitations surrounding the recommendations section in that there are many more recommendations for policy interventions that can be made and could be successful for increasing vaccination rates. However, only a few that were deemed most important and relevant were mentioned by the author. Lastly, a hurdle in the research was the fact that there was a plethora of information regarding the topic, so narrowing down to the sources deemed important and relevant to my research was a difficult task.

Future Research

As the author conducted research, there were questions that were brought forward that were not anticipated originally by the author. This included the fact that many communities in the United States that are affected by disease outbreaks usually consist of unvaccinated ethnic or religious populations in addition to outbreaks in natural born American populations. For future research, the author could look at these communities and analyze the demographic makeup of them, determine the breakdown of religious beliefs in these different communities to see if religious beliefs correlates with their resistance, and then further investigate why there are other types of resistance in these

ethnic or religious populations and how that resistance compares and contrasts to that of natural born American anti-vaxxers.

In addition, it would be interesting to research the manifestation of fears associated with immigration due to decreased vaccination rates and increased disease outbreaks in the United States because disease that is spread in the United States often originates overseas. Lastly, as vaccination has not been an issue that has been politicized heavily, going further to research the potential implications of politicizing the anti-vaxx movement would also be something to consider. As our political system is becoming more and more polarized, if the issue of vaccination becomes politicized, it could have serious implications that could affect the passage of compulsory vaccination laws in the future.

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Recommended Child and Adolescent Immunization Schedule for ages 18 years or younger

UNITED STATES 2019

Vaccines in the Child and Adolescent Immunization Schedule*

Vaccines	Abbreviations	Trade names
Diphtheria, tetanus, and acellular pertussis vaccine	**DTaP**	Daptacel Infanrix
Diphtheria, tetanus vaccine	**DT**	No Trade Name
Haemophilus influenzae type b vaccine	**Hib (PRP-T)** **Hib (PRP-OMP)**	ActHIB Hiberix PedvaxHIB
Hepatitis A vaccine	**HepA**	Havrix Vaqta
Hepatitis B vaccine	**HepB**	Engerix-B Recombivax HB
Human papillomavirus vaccine	**HPV**	Gardasil 9
Influenza vaccine (inactivated)	**IIV**	Multiple
Influenza vaccine (live, attenuated)	**LAIV**	FluMist
Measles, mumps, and rubella vaccine	**MMR**	M-M-R II
Meningococcal serogroups A, C, W, Y vaccine	**MenACWY-D**	Menactra
	MenACWY-CRM	Menveo
Meningococcal serogroup B vaccine	**MenB-4C**	Bexsero
	MenB-FHbp	Trumenba
Pneumococcal 13-valent conjugate vaccine	**PCV13**	Prevnar 13
Pneumococcal 23-valent polysaccharide vaccine	**PPSV23**	Pneumovax
Poliovirus vaccine (inactivated)	**IPV**	IPOL
Rotavirus vaccine	**RV1** **RV5**	Rotarix RotaTeq
Tetanus, diphtheria, and acellular pertussis vaccine	**Tdap**	Adacel Boostrix
Tetanus and diphtheria vaccine	**Td**	Tenivac Td vaccine
Varicella vaccine	**VAR**	Varivax
Combination Vaccines *(Use combination vaccines instead of separate injections when appropriate)*		
DTaP, hepatitis B, and inactivated poliovirus vaccine	**DTaP-HepB-IPV**	Pediarix
DTaP, inactivated poliovirus, and *Haemophilus influenzae* type b vaccine	**DTaP-IPV/Hib**	Pentacel
DTaP and inactivated poliovirus vaccine	**DTaP-IPV**	Kinrix Quadracel
Measles, mumps, rubella, and varicella vaccines	**MMRV**	ProQuad

*Administer recommended vaccines if immunization history is incomplete or unknown. Do not restart or add doses to vaccine series for extended intervals between doses. When a vaccine is not administered at the recommended age, administer at a subsequent visit. The use of trade names is for identification purposes only and does not imply endorsement by the ACIP or CDC.

How to use the child/adolescent immunization schedule

1 Determine recommended vaccine by age **(Table 1)**

2 Determine recommended interval for catch-up vaccination **(Table 2)**

3 Assess need for additional recommended vaccines by medical condition and other indications **(Table 3)**

4 Review vaccine types, frequencies, intervals, and considerations for special situations **(Notes)**

Recommended by the Advisory Committee on Immunization Practices (www.cdc.gov/vaccines/acip) and approved by the Centers for Disease Control and Prevention (www.cdc.gov), American Academy of Pediatrics (www.aap.org), American Academy of Family Physicians (www.aafp.org), and American College of Obstetricians and Gynecologists (www.acog.org).

Report

- Suspected cases of reportable vaccine-preventable diseases or outbreaks to your state or local health department
- Clinically significant adverse events to the Vaccine Adverse Event Reporting System (VAERS) at www.vaers.hhs.gov or (800-822-7967)

Download the CDC Vaccine Schedules App for providers at www.cdc.gov/vaccines/schedules/hcp/schedule-app.html.

Helpful information

- Complete ACIP recommendations: www.cdc.gov/vaccines/hcp/acip-recs/index.html
- General Best Practice Guidelines for Immunization: www.cdc.gov/vaccines/hcp/acip-recs/general-recs/index.html
- Outbreak information (including case identification and outbreak response), see Manual for the Surveillance of Vaccine-Preventable Diseases: www.cdc.gov/vaccines/pubs/surv-manual

U.S. Department of Health and Human Services
Centers for Disease Control and Prevention

Table 1a - Recommended Child and Adolescent Immunization Schedule for ages 18 years or younger, United States, 2019

These recommendations must be read with the Notes that follow. For those who fall behind or start late, provide catch-up vaccination at the earliest opportunity as indicated by the dark gray bars in Table 1. To determine minimum intervals between doses, see the catch-up schedule (Table 2). School entry and adolescent vaccine age groups are marked with a star.

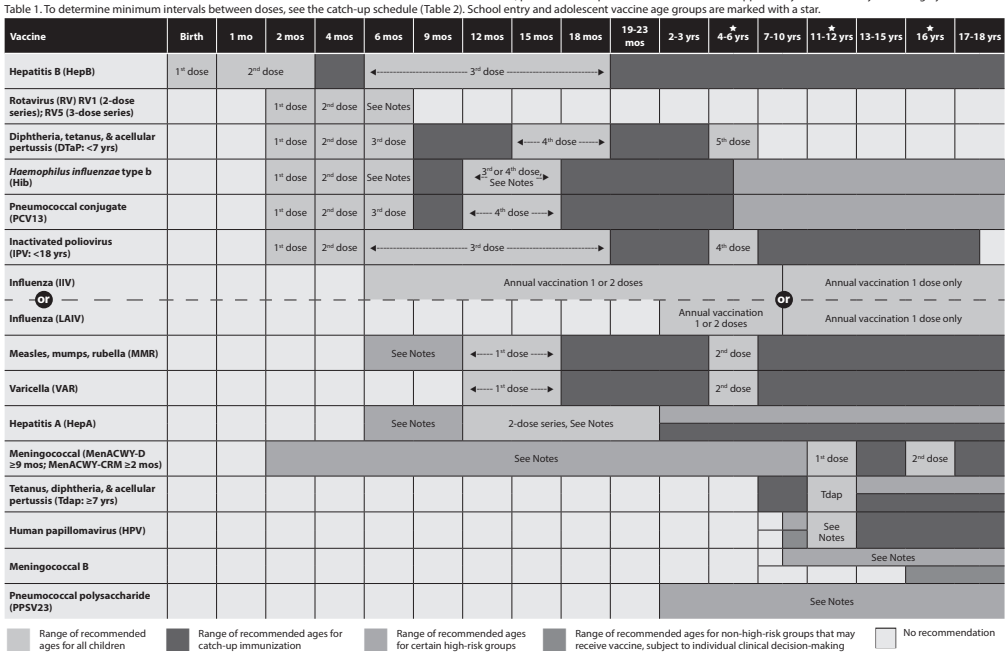


Table 2a - Catch-up immunization schedule for persons aged 4 months-18 years who start late or who are more than 1 month behind, United States, 2019

The figure below provides catch-up schedules and minimum intervals between doses for children whose vaccinations have been delayed. A vaccine series does not need to be restarted, regardless of the time that has elapsed between doses. Use the section appropriate for the child's age. Always use this table in conjunction with Table 1 and the notes that follow.

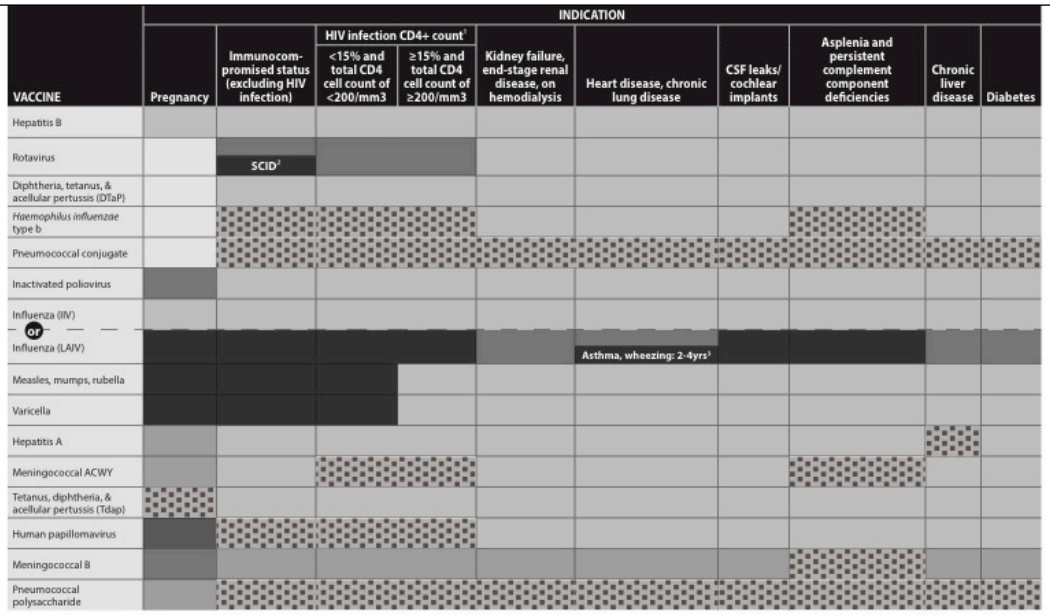
Children age 4 months through 6 years

Vaccine	Minimum Age for Dose 1	Minimum Interval Between Doses			
		Dose 1 to Dose 2	Dose 2 to Dose 3	Dose 3 to Dose 4	Dose 4 to Dose 5
Hepatitis B	Birth	**4 weeks**	**8 weeks *and* at least 16 weeks after first dose.** Minimum age for the final dose is 24 weeks.		
Rotavirus	6 weeks Maximum age for first dose is 14 weeks, 6 days	**4 weeks**	**4 weeks** Maximum age for final dose is 8 months, 0 days.		
Diphtheria, tetanus, and acellular pertussis	6 weeks	**4 weeks**	**4 weeks**	**6 months**	**6 months**
Haemophilus influenzae type b	6 weeks	**No further doses needed** if first dose was administered at age 15 months or older. **4 weeks** if first dose was administered before the 1st birthday. **8 weeks (as final dose)** if first dose was administered at age 12 through 14 months.	**No further doses needed** if previous dose was administered at age 15 months or older. **4 weeks** if current age is younger than 12 months ***and*** first dose was administered at younger than age 7 months, ***and*** at least 1 previous dose was PRP-T (ActHib, Pentacel, Hiberix) or unknown. **8 weeks *and* age 12 through 59 months (as final dose)** if current age is younger than 12 months ***and*** first dose was administered at age 7 through 11 months; OR if current age is 12 through 59 months ***and*** first dose was administered before the 1st birthday, ***and*** second dose administered at younger than 15 months; OR if both doses were PRP-OMP (PedvaxHIB; Comvax) ***and*** were administered before the 1st birthday.	**8 weeks (as final dose)** This dose only necessary for children age 12 through 59 months who received 3 doses before the 1st birthday.	
Pneumococcal conjugate	6 weeks	**No further doses needed** for healthy children if first dose was administered at age 24 months or older. **4 weeks** if first dose administered before the 1st birthday. **8 weeks (as final dose for healthy children)** if first dose was administered at the 1st birthday or after.	**No further doses needed** for healthy children if previous dose administered at age 24 months or older. **4 weeks** if current age is younger than 12 months and previous dose given at <7 months old. **8 weeks (as final dose for healthy children)** if previous dose given between 7-11 months (wait until at least 12 months old); OR if current age is 12 months or older and at least 1 dose was given before age 12 months.	**8 weeks (as final dose)** This **dose** only necessary for children age 12 through 59 months who received 3 doses before age 12 months or for children at high risk who received 3 doses at any age.	
Inactivated poliovirus	6 weeks	**4 weeks**	4 weeks if current age is < 4 years. 6 months (as final dose) if current age is 4 years or older.	**6 months** (minimum age 4 years for final dose).	
Measles, mumps, rubella	12 months	**4 weeks**			
Varicella	12 months	**3 months**			
Hepatitis A	12 months	**6 months**			
Meningococcal	2 months MenACWY-CRM 9 months MenACWY-D	**8 weeks**	See Notes	See Notes	

Children and adolescents age 7 through 18 years

Meningococcal	Not Applicable (N/A)	**8 weeks**			
Tetanus, diphtheria; tetanus, diphtheria, and acellular pertussis	7 years	**4 weeks**	**4 weeks** if first dose of DTaP/DT was administered before the 1st birthday. **6 months (as final dose)** if first dose of DTaP/DT or Tdap/Td was administered at or after the 1st birthday.	**6 months** if first dose of DTaP/DT was administered before the 1st birthday.	
Human papillomavirus	9 years	**Routine dosing intervals are recommended.**			
Hepatitis A	N/A	**6 months**			
Hepatitis B	N/A	**4 weeks**	**8 weeks *and*** at least 16 weeks after first dose.		
Inactivated poliovirus	N/A	**4 weeks**	**6 months** A fourth dose is not necessary if the third dose was administered at age 4 years or older and at least 6 months after the previous dose.	A fourth dose of IPV is indicated if all previous doses were administered at <4 years or if the third dose was administered <6 months after the second dose.	
Measles, mumps, rubella	N/A	**4 weeks**			
Varicella	N/A	**3 months** if younger than age 13 years. **4 weeks** if age 13 years or older.			

Table 3a - Recommended Child and Adolescent Immunization Schedule by Medical Indication, United States, 2019



1 For additional information regarding HIV laboratory parameters and use of live vaccines, see the General Best Practice Guidelines for Immunization "Altered Immunocompetence" at www.cdc.gov/vaccines/hcp/acip-recs/general-recs/immunocompetence.html, and Table 4-1 (footnote D) at: www.cdc.gov/vaccines/hcp/acip-recs/general-recs/contraindications.html.
2 Severe Combined Immunodeficiency
3 LAIV contraindicated for children 2–4 years of age with asthma or wheezing during the preceding 12 months.

Notes — Recommended Child and Adolescent Immunization Schedule for ages 18 years or younger, United States, 2019

For vaccine recommendations for persons 19 years of age and older, see the Recommended Adult Immunization Schedule.

Additional information

- Consult relevant ACIP statements for detailed recommendations at www.cdc.gov/vaccines/hcp/acip-recs/index.html.
- For information on contraindications and precautions for the use of a vaccine, consult the General Best Practice Guidelines for Immunization and relevant ACIP statements at www.cdc.gov/vaccines/hcp/acip-recs/index.html.
- For calculating intervals between doses, 4 weeks = 28 days. Intervals of ≥4 months are determined by calendar months.
- Within a number range (e.g., 12–18), a dash (–) should be read as "through."
- Vaccine doses administered ≤4 days before the minimum age or interval are considered valid. Doses of any vaccine administered ≥5 days earlier than the minimum age or minimum interval should not be counted as valid and should be repeated as age-appropriate. The repeat dose should be spaced after the invalid dose by the recommended minimum interval. For further details, see Table 3-1, Recommended and minimum ages and intervals between vaccine doses, in General Best Practice Guidelines for Immunization at www.cdc.gov/vaccines/hcp/acip-recs/general-recs/timing.html.
- Information on travel vaccine requirements and recommendations is available at wwwnc.cdc.gov/travel/.
- For vaccination of persons with immunodeficiencies, see Table 8-1, Vaccination of persons with primary and secondary immunodeficiencies, in General Best Practice Guidelines for Immunization at www.cdc.gov/vaccines/hcp/acip-recs/general-recs/immunocompetence.html, and Immunization in Special Clinical Circumstances (In: Kimberlin DW, Brady MT, Jackson MA, Long SS, eds. *Red Book: 2018 Report of the Committee on Infectious Diseases*. 31st ed. Itasca, IL: American Academy of Pediatrics; 2018:67–111).
- For information regarding vaccination in the setting of a vaccine-preventable disease outbreak, contact your state or local health department.
- The National Vaccine Injury Compensation Program (VICP) is a no-fault alternative to the traditional legal system for resolving vaccine injury claims. All routine child and adolescent vaccines are covered by VICP except for pneumococcal polysaccharide vaccine (PPSV23). For more information, see www.hrsa.gov/vaccinecompensation/index.html.

Diphtheria, tetanus, and pertussis (DTaP) vaccination (minimum age: 6 weeks [4 years for Kinrix or Quadracel])

Routine vaccination

- 5-dose series at 2, 4, 6, 15–18 months, 4–6 years
  - **Prospectively:** Dose 4 may be given as early as age 12 months if at least 6 months have elapsed since dose 3.
  - **Retrospectively:** A 4th dose that was inadvertently given as early as 12 months may be counted if at least 4 months have elapsed since dose 3.

Catch-up vaccination

- Dose 5 is not necessary if dose 4 was administered at age 4 years or older.
- For other catch-up guidance, see Table 2.

Haemophilus influenzae type b vaccination (minimum age: 6 weeks)

Routine vaccination

- **ActHIB, Hiberix, or Pentacel:** 4-dose series at 2, 4, 6, 12–15 months
- **PedvaxHIB:** 3-dose series at 2, 4, 12–15 months

Catch-up vaccination

- **Dose 1 at 7–11 months:** Administer dose 2 at least 4 weeks later and dose 3 (final dose) at 12–15 months or 8 weeks after dose 2 (whichever is later).
- **Dose 1 at 12–14 months:** Administer dose 2 (final dose) at least 8 weeks after dose 1.
- **Dose 1 before 12 months and dose 2 before 15 months:** Administer dose 3 (final dose) 8 weeks after dose 2.
- **2 doses of PedvaxHIB before 12 months:** Administer dose 3 (final dose) at 12–59 months and at least 8 weeks after dose 2.
- **Unvaccinated at 15–59 months:** 1 dose
- For other catch-up guidance, see Table 2.

Special situations

- **Chemotherapy or radiation treatment:**
  12–59 months
  - Unvaccinated or only 1 dose before age 12 months: 2 doses, 8 weeks apart
  - 2 or more doses before age 12 months: 1 dose at least 8 weeks after previous dose

  Doses administered within 14 days of starting therapy or during therapy should be repeated at least 3 months after therapy completion.
- **Hematopoietic stem cell transplant (HSCT):**
  - 3-dose series 4 weeks apart starting 6 to 12 months after successful transplant regardless of Hib vaccination history
- **Anatomic or functional asplenia (including sickle cell disease):**
  12–59 months
  - Unvaccinated or only 1 dose before 12 months: 2 doses, 8 weeks apart
  - 2 or more doses before 12 months:1 dose at least 8 weeks after previous dose

  Unvaccinated persons age 5 years or older*
  - 1 dose
- **Elective splenectomy:**
  Unvaccinated persons age 15 months or older*
  - 1 dose (preferably at least 14 days before procedure)
- **HIV infection:**
  12–59 months
  - Unvaccinated or only 1 dose before age 12 months: 2 doses, 8 weeks apart
  - 2 or more doses before age 12 months: 1 dose at least 8 weeks after previous dose

  Unvaccinated persons age 5–18 years*
  - 1 dose
- **Immunoglobulin deficiency, early component complement deficiency:**
  12–59 months
  - Unvaccinated or only 1 dose before age 12 months: 2 doses, 8 weeks apart
  - 2 or more doses before age 12 months: 1 dose at least 8 weeks after previous dose

**Unvaccinated* = Less than routine series (through 14 months) OR no doses (14 months or older)

Notes — Recommended Child and Adolescent Immunization Schedule for ages 18 years or younger, United States, 2019

Hepatitis A vaccination (minimum age: 12 months for routine vaccination)

Routine vaccination

- 2-dose series (**Havrix** 6–12 months apart or **Vaqta** 6–18 months apart, minimum interval 6 months); a series begun before the 2nd birthday should be completed even if the child turns 2 before the second dose is administered.

Catch-up vaccination

- Anyone 2 years of age or older may receive HepA vaccine if desired. Minimum interval between doses: 6 months
- Adolescents 18 years and older may receive the combined HepA and HepB vaccine, **Twinrix**, as a 3-dose series (0, 1, and 6 months) or 4-dose series (0, 7, and 21–30 days, followed by a dose at 12 months).

International travel

- Persons traveling to or working in countries with high or intermediate endemic hepatitis A (wwwnc.cdc.gov/travel/):
  - **Infants age 6–11 months**: 1 dose before departure; revaccinate with 2 doses, separated by 6–18 months, between 12 to 23 months of age.
  - **Unvaccinated age 12 months and older**: 1st dose as soon as travel considered

Special situations

At risk for hepatitis A infection: 2-dose series as above

- **Chronic liver disease**
- **Clotting factor disorders**
- **Men who have sex with men**
- **Injection or non-injection drug use**
- **Homelessness**
- **Work with hepatitis A virus** in research laboratory or nonhuman primates with hepatitis A infection
- **Travel** in countries with high or intermediate endemic hepatitis A
- **Close, personal contact with international adoptee** (e.g., household or regular babysitting) in first 60 days after arrival from country with high or intermediate endemic hepatitis A (administer dose 1 as soon as adoption is planned, at least 2 weeks before adoptee's arrival)

Hepatitis B vaccination (minimum age: birth)

Birth dose (monovalent HepB vaccine only)

- **Mother is HBsAg-negative:** 1 dose within 24 hours of birth for **all** medically stable infants ≥2,000 grams. Infants <2,000 grams: administer 1 dose at chronological age 1 month or hospital discharge.
- **Mother is HBsAg-positive:**
  - Administer **HepB vaccine** and **0.5 mL of hepatitis B immune globulin (HBIG)** (at separate anatomic sites) within 12 hours of birth, regardless of birth weight. For infants <2,000 grams, administer 3 additional doses of vaccine (total of 4 doses) beginning at age 1 month.
  - Test for HBsAg and anti-HBs at age 9–12 months. If HepB series is delayed, test 1–2 months after final dose.
- **Mother's HBsAg status is unknown:**
  - Administer **HepB vaccine** within 12 hours of birth, regardless of birth weight.
  - For infants <2,000 grams, administer **0.5 mL of HBIG** in addition to HepB vaccine within 12 hours of birth. Administer 3 additional doses of vaccine (total of 4 doses) beginning at age 1 month.
  - Determine mother's HBsAg status as soon as possible. If mother is HBsAg-positive, administer **0.5 mL of HBIG** to infants ≥2,000 grams as soon as possible, but no later than 7 days of age.

Routine series

- 3-dose series at 0, 1–2, 6–18 months (use monovalent HepB vaccine for doses administered before age 6 weeks)
- Infants who did not receive a birth dose should begin the series as soon as feasible (see Table 2).
- Administration of **4 doses** is permitted when a combination vaccine containing HepB is used after the birth dose.
- **Minimum age** for the final (3rd or 4th) dose: 24 weeks
- **Minimum intervals:** dose 1 to dose 2: 4 weeks / dose 2 to dose 3: 8 weeks / dose 1 to dose 3: 16 weeks (when 4 doses are administered, substitute "dose 4" for "dose 3" in these calculations)

Catch-up vaccination

- Unvaccinated persons should complete a 3-dose series at 0, 1–2, 6 months.
- Adolescents age 11–15 years may use an alternative 2-dose schedule with at least 4 months between doses (adult formulation **Recombivax HB** only).
- Adolescents 18 years and older may receive a 2-dose series of HepB **(Heplisav-B)** at least 4 weeks apart.
- Adolescents 18 years and older may receive the combined HepA and HepB vaccine, **Twinrix**, as a 3-dose series (0, 1, and 6 months) or 4-dose series (0, 7, and 21–30 days, followed by a dose at 12 months).
- For other catch-up guidance, see Table 2.

Human papillomavirus vaccination (minimum age: 9 years)

Routine and catch-up vaccination

- HPV vaccination routinely recommended for all adolescents **age 11–12 years (can start at age 9 years)** and through age 18 years if not previously adequately vaccinated
- 2- or 3-dose series depending on age at initial vaccination:
  - **Age 9 through 14 years at initial vaccination**: 2-dose series at 0, 6–12 months (minimum interval: 5 months; repeat dose if administered too soon)
  - **Age 15 years or older at initial vaccination**: 3-dose series at 0, 1–2 months, 6 months (minimum intervals: dose 1 to dose 2: 4 weeks / dose 2 to dose 3: 12 weeks / dose 1 to dose 3: 5 months; repeat dose if administered too soon)
- If completed valid vaccination series with any HPV vaccine, no additional doses needed

Special situations

- **Immunocompromising conditions, including HIV infection:** 3-dose series as above
- **History of sexual abuse or assault:** Start at age 9 years
- **Pregnancy:** HPV vaccination not recommended until after pregnancy; no intervention needed if vaccinated while pregnant; pregnancy testing not needed before vaccination

Inactivated poliovirus vaccination (minimum age: 6 weeks)

Routine vaccination

- 4-dose series at ages 2, 4, 6–18 months, 4–6 years; administer the final dose on or after the 4th birthday and at least 6 months after the previous dose.
- 4 or more doses of IPV can be administered before the 4th birthday when a combination vaccine containing IPV is used. However, a dose is still recommended after the 4th birthday and at least 6 months after the previous dose.

Catch-up vaccination

- In the first 6 months of life, use minimum ages and intervals only for travel to a polio-endemic region or during an outbreak.
- IPV is not routinely recommended for U.S. residents 18 years and older.

Series containing oral polio vaccine (OPV), either mixed OPV-IPV or OPV-only series:

- Total number of doses needed to complete the series is the same as that recommended for the U.S. IPV schedule. See www.cdc.gov/mmwr/volumes/66/wr/mm6601a6.htm?s_cid=mm6601a6_w.

Notes — Recommended Child and Adolescent Immunization Schedule for ages 18 years or younger, United States, 2019

- Only trivalent OPV (tOPV) counts toward the U.S. vaccination requirements. For guidance to assess doses documented as "OPV," see www.cdc.gov/mmwr/volumes/66/wr/mm6606a7.htm?s_cid=mm6606a7_w.
- For other catch-up guidance, see Table 2.

Influenza vaccination
(minimum age: 6 months [IIV], 2 years [LAIV], 18 years [RIV])

Routine vaccination
- 1 dose any influenza vaccine appropriate for age and health status annually (2 doses separated by at least 4 weeks for **children 6 months–8 years** who did not receive at least 2 doses of influenza vaccine before July 1, 2018)

Special situations
- **Egg allergy, hives only**: Any influenza vaccine appropriate for age and health status annually
- **Egg allergy more severe than hives** (e.g., angioedema, respiratory distress): Any influenza vaccine appropriate for age and health status annually in medical setting under supervision of health care provider who can recognize and manage severe allergic conditions
- **LAIV should not be used for** those with a history of severe allergic reaction to any component of the vaccine (excluding egg) or to a previous dose of any influenza vaccine, children and adolescents receiving concomitant aspirin or salicylate-containing medications, children age 2 through 4 years with a history of asthma or wheezing, those who are immunocompromised due to any cause (including immunosuppression caused by medications and HIV infection), anatomic and functional asplenia, cochlear implants, cerebrospinal fluid-oropharyngeal communication, close contacts and caregivers of severely immunosuppressed persons who require a protected environment, pregnancy, and persons who have received influenza antiviral medications within the previous 48 hours.

Measles, mumps, and rubella vaccination
(minimum age: 12 months for routine vaccination)

Routine vaccination
- 2-dose series at 12–15 months, 4–6 years
- Dose 2 may be administered as early as 4 weeks after dose 1.

Catch-up vaccination
- Unvaccinated children and adolescents: 2 doses at least 4 weeks apart
- The maximum age for use of *MMRV* is 12 years.

Special situations

International travel
- **Infants age 6–11 months:** 1 dose before departure; revaccinate with 2 doses at 12–15 months (12 months for children in high-risk areas) and dose 2 as early as 4 weeks later.
- **Unvaccinated children age 12 months and older:** 2-dose series at least 4 weeks apart before departure

Meningococcal serogroup A,C,W,Y vaccination
(minimum age: 2 months [MenACWY-CRM, Menveo], 9 months [MenACWY-D, Menactra])

Routine vaccination
- 2-dose series: 11–12 years, 16 years

Catch-up vaccination
- Age 13–15 years: 1 dose now and booster at age 16–18 years (minimum interval: 8 weeks)
- Age 16–18 years: 1 dose

Special situations

Anatomic or functional asplenia (including sickle cell disease), HIV infection, persistent complement component deficiency, eculizumab use:
- **Menveo**
  - Dose 1 at age 8 weeks: 4-dose series at 2, 4, 6, 12 months
  - Dose 1 at age 7–23 months: 2-dose series (dose 2 at least 12 weeks after dose 1 and after the 1st birthday)
  - Dose 1 at age 24 months or older: 2-dose series at least 8 weeks apart
- **Menactra**
  - **Persistent complement component deficiency:**
    - Age 9–23 months: 2 doses at least 12 weeks apart
    - Age 24 months or older: 2 doses at least 8 weeks apart
  - **Anatomic or functional asplenia, sickle cell disease, or HIV infection:**
    - **Age 9–23 months**: Not recommended
    - **24 months or older**: 2 doses at least 8 weeks apart
    - **Menactra** must be administered at least 4 weeks after completion of PCV13 series.

Travel in countries with hyperendemic or epidemic meningococcal disease, including countries in the African meningitis belt or during the Hajj (wwwnc.cdc.gov/travel/)**:**
- Children age less than 24 months:
  - **Menveo (age 2–23 months):**
    - Dose 1 at 8 weeks: 4-dose series at 2, 4, 6, 12 months
    - Dose 1 at 7–23 months: 2-dose series (dose 2 at least 12 weeks after dose 1 and after the 1st birthday)
  - **Menactra (age 9–23 months):**
    - 2-dose series (dose 2 at least 12 weeks after dose 1; dose 2 may be administered as early as 8 weeks after dose 1 in travelers)
- Children age 2 years or older: 1 dose **Menveo** or **Menactra**

First-year college students who live in residential housing (if not previously vaccinated at age 16 years or older) or military recruits:
- 1 dose **Menveo** or **Menactra**

Note: Menactra should be administered either before or at the same time as DTaP. For MenACWY booster dose recommendations for groups listed under "Special situations" above and additional meningococcal vaccination information, see meningococcal *MMWR* publications at www.cdc.gov/vaccines/hcp/acip-recs/vacc-specific/mening.html.

Meningococcal serogroup B vaccination
(minimum age: 10 years [MenB-4C, Bexsero; MenB-FHbp, Trumenba])

Clinical discretion
- MenB vaccine may be administered based on individual clinical decision to **adolescents not at increased risk** age 16–23 years (preferred age 16–18 years):
- **Bexsero:** 2-dose series at least 1 month apart
- **Trumenba:** 2-dose series at least 6 months apart; if dose 2 is administered earlier than 6 months, administer a 3rd dose at least 4 months after dose 2.

Special situations

Anatomic or functional asplenia (including sickle cell disease), persistent complement component deficiency, eculizumab use:
- **Bexsero:** 2-dose series at least 1 month apart
- **Trumenba:** 3-dose series at 0, 1–2, 6 months

Bexsero and **Trumenba** are not interchangeable; the same product should be used for all doses in a series.
For additional meningococcal vaccination information, see meningococcal *MMWR* publications at www.cdc.gov/vaccines/hcp/acip-recs/vacc-specific/mening.html.

Recommended Adult Immunization Schedule for ages 19 years or older — UNITED STATES 2019

How to use the adult immunization schedule

1 Determine recommended vaccinations by age **(Table 1)**

2 Assess need for additional recommended vaccinations by medical condition and other indications **(Table 2)**

3 Review vaccine types, frequencies, and intervals, and considerations for special situations **(Notes)**

Recommended by the Advisory Committee on Immunization Practices (www.cdc.gov/vaccines/acip) and approved by the Centers for Disease Control and Prevention (www.cdc.gov), American College of Physicians (www.acponline.org), American Academy of Family Physicians (www.aafp.org), American College of Obstetricians and Gynecologists (www.acog.org), and American College of Nurse-Midwives (www.midwife.org).

Vaccines in the Adult Immunization Schedule*

Vaccines	Abbreviations	Trade names
Haemophilus influenzae type b vaccine	Hib	ActHIB Hiberix
Hepatitis A vaccine	HepA	Havrix Vaqta
Hepatitis A and hepatitis B vaccine	HepA-HepB	Twinrix
Hepatitis B vaccine	HepB	Engerix-B Recombivax HB Heplisav-B
Human papillomavirus vaccine	HPV vaccine	Gardasil 9
Influenza vaccine, inactivated	IIV	Many brands
Influenza vaccine, live attenuated	LAIV	FluMist Quadrivalent
Influenza vaccine, recombinant	RIV	Flublok Quadrivalent
Measles, mumps, and rubella vaccine	MMR	M-M-R II
Meningococcal serogroups A, C, W, Y vaccine	MenACWY	Menactra Menveo
Meningococcal serogroup B vaccine	MenB-4C MenB-FHbp	Bexsero Trumenba
Pneumococcal 13-valent conjugate vaccine	PCV13	Prevnar 13
Pneumococcal 23-valent polysaccharide vaccine	PPSV23	Pneumovax
Tetanus and diphtheria toxoids	Td	Tenivac Td vaccine
Tetanus and diphtheria toxoids and acellular pertussis vaccine	Tdap	Adacel Boostrix
Varicella vaccine	VAR	Varivax
Zoster vaccine, recombinant	RZV	Shingrix
Zoster vaccine live	ZVL	Zostavax

*Administer recommended vaccines if vaccination history is incomplete or unknown. Do not restart or add doses to vaccine series for extended intervals between doses. The use of trade names is for identification purposes only and does not imply endorsement by the ACIP or CDC.

Report
- Suspected cases of reportable vaccine-preventable diseases or outbreaks to the local or state health department
- Clinically significant postvaccination reactions to the Vaccine Adverse Event Reporting System at www.vaers.hhs.gov or 800-822-7967

Injury claims
All vaccines included in the adult immunization schedule except pneumococcal 23-valent polysaccharide and zoster vaccines are covered by the Vaccine Injury Compensation Program. Information on how to file a vaccine injury claim is available at www.hrsa.gov/vaccinecompensation or 800-338-2382.

Questions or comments
Contact www.cdc.gov/cdc-info or 800-CDC-INFO (800-232-4636), in English or Spanish, 8 a.m.–8 p.m. ET, Monday through Friday, excluding holidays.

Download the CDC Vaccine Schedules App for providers at www.cdc.gov/vaccines/schedules/hcp/schedule-app.html.

Helpful information
- Complete ACIP recommendations: www.cdc.gov/vaccines/hcp/acip-recs/index.html
- General Best Practice Guidelines for Immunization (including contraindications and precautions): www.cdc.gov/vaccines/hcp/acip-recs/general-recs/index.html
- Vaccine Information Statements: www.cdc.gov/vaccines/hcp/vis/index.html
- Manual for the Surveillance of Vaccine-Preventable Diseases (including case identification and outbreak response): www.cdc.gov/vaccines/pubs/surv-manual
- Travel vaccine recommendations: www.cdc.gov/travel
- Recommended Child and Adolescent Immunization Schedule, United States, 2019: www.cdc.gov/vaccines/schedules/hcp/child-adolescent.html

U.S. Department of Health and Human Services
Centers for Disease Control and Prevention

Table 1b - Recommended Adult Immunization Schedule by Age Group, United States, 2019

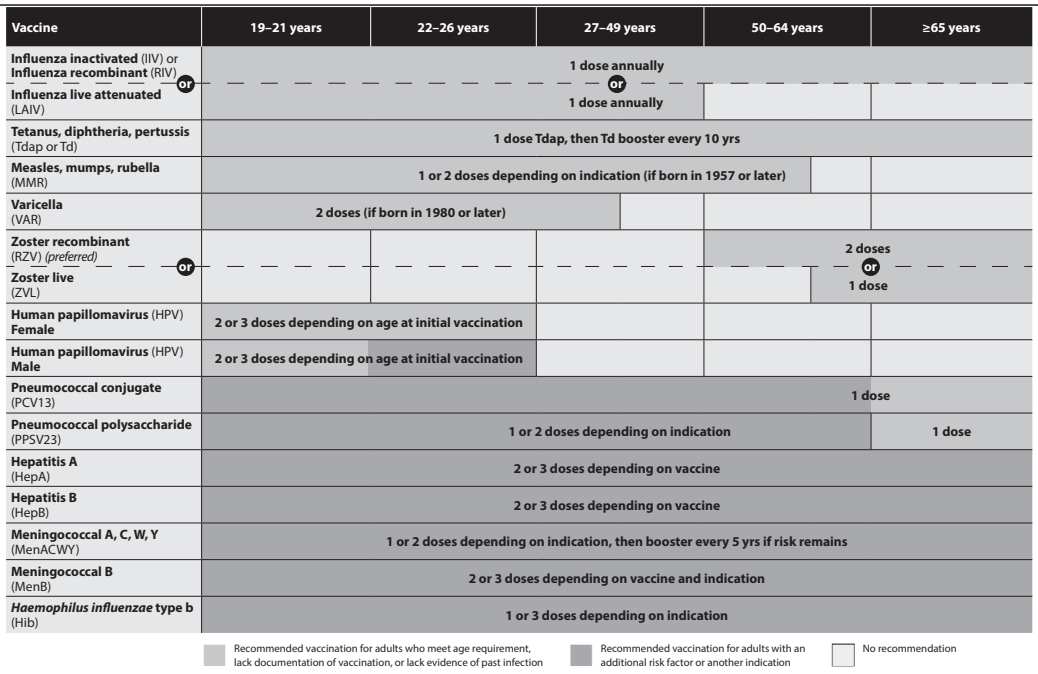
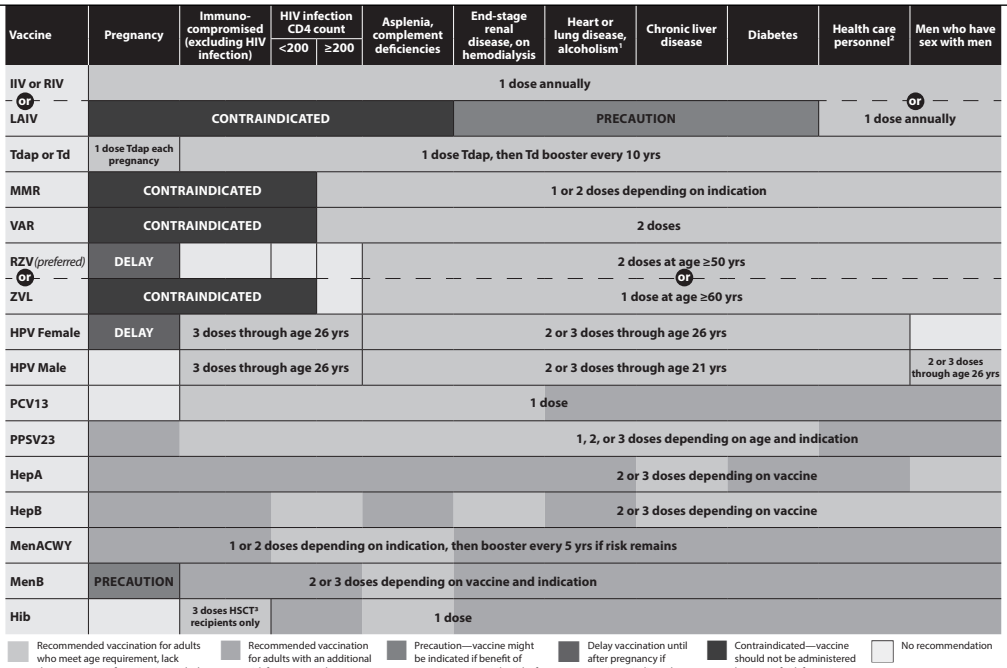


Table 2b - Recommended Adult Immunization Schedule by Medical Condition and Other Indications, United States, 2019



1. Precaution for LAIV does not apply to alcoholism. **2.** See notes for influenza; hepatitis B; measles, mumps, and rubella; and varicella vaccinations. **3.** Hematopoietic stem cell transplant.

Notes — Recommended Adult Immunization Schedule United States, 2019

Haemophilus influenzae type b vaccination

Special situations

- **Anatomical or functional asplenia (including sickle cell disease)**: 1 dose Hib if previously did not receive Hib; if elective splenectomy, 1 dose Hib, preferably at least 14 days before splenectomy
- **Hematopoietic stem cell transplant** (HSCT): 3-dose series Hib 4 weeks apart starting 6–12 months after successful transplant, regardless of Hib vaccination history

Hepatitis A vaccination

Routine vaccination

- **Not at risk but want protection from hepatitis A** (identification of risk factor not required): 2-dose series HepA (Havrix 6–12 months apart or Vaqta 6–18 months apart [minimum interval: 6 months]) or 3-dose series HepA-HepB (Twinrix at 0, 1, 6 months [minimum intervals: 4 weeks between doses 1 and 2, 5 months between doses 2 and 3])

Special situations

- **At risk for hepatitis A virus infection**: 2-dose series HepA or 3-dose series HepA-HepB as above
  - **Chronic liver disease**
  - **Clotting factor disorders**
  - **Men who have sex with men**
  - **Injection or non-injection drug use**
  - **Homelessness**
  - **Work with hepatitis A virus** in research laboratory or nonhuman primates with hepatitis A virus infection
  - **Travel in countries with high or intermediate endemic hepatitis A**
  - **Close personal contact with international adoptee** (e.g., household, regular babysitting) in first 60 days after arrival from country with high or intermediate endemic hepatitis A (administer dose 1 as soon as adoption is planned, at least 2 weeks before adoptee's arrival)

Hepatitis B vaccination

Routine vaccination

- **Not at risk but want protection from hepatitis B** (identification of risk factor not required): 2- or 3-dose series HepB (2-dose series Heplisav-B at least 4 weeks apart [2-dose series HepB only applies when 2 doses of Heplisav-B are used at least 4 weeks apart] or 3-dose series Engerix-B or Recombivax HB at 0, 1, 6 months [minimum intervals: 4 weeks between doses 1 and 2, 8 weeks between doses 2 and 3, 16 weeks between doses 1 and 3]) or 3-dose series HepA-HepB (Twinrix at 0, 1, 6 months [minimum intervals: 4 weeks between doses 1 and 2, 5 months between doses 2 and 3])

Special situations

- **At risk for hepatitis B virus infection**: 2-dose (Heplisav-B) or 3-dose (Engerix-B, Recombivax HB) series HepB, or 3-dose series HepA-HepB as above
  - **Hepatitis C virus infection**
  - **Chronic liver disease** (e.g., cirrhosis, fatty liver disease, alcoholic liver disease, autoimmune hepatitis, alanine aminotransferase [ALT] or aspartate aminotransferase [AST] level greater than twice upper limit of normal)
  - **HIV infection**
  - **Sexual exposure risk** (e.g., sex partners of hepatitis B surface antigen (HBsAg)-positive persons; sexually active persons not in mutually monogamous relationships, persons seeking evaluation or treatment for a sexually transmitted infection, men who have sex with men)
  - **Current or recent injection drug use**
  - **Percutaneous or mucosal risk for exposure to blood** (e.g., household contacts of HBsAg-positive persons; residents and staff of facilities for developmentally disabled persons; health care and public safety personnel with reasonably anticipated risk for exposure to blood or blood-contaminated body fluids; hemodialysis, peritoneal dialysis, home dialysis, and predialysis patients; persons with diabetes mellitus age younger than 60 years and, at discretion of treating clinician, those age 60 years or older)
  - **Incarcerated persons**
  - **Travel in countries with high or intermediate endemic hepatitis B**

Human papillomavirus vaccination

Routine vaccination

- **Females through age 26 years and males through age 21 years:** 2- or 3-dose series HPV vaccine depending on age at initial vaccination; males age 22 through 26 years may be vaccinated based on individual clinical decision (HPV vaccination routinely recommended at age 11–12 years)
- **Age 15 years or older at initial vaccination**: 3-dose series HPV vaccine at 0, 1–2, 6 months (minimum intervals: 4 weeks between doses 1 and 2, 12 weeks between doses 2 and 3, 5 months between doses 1 and 3; repeat dose if administered too soon)
- **Age 9 through 14 years at initial vaccination and received 1 dose, or 2 doses less than 5 months apart**: 1 dose HPV vaccine
- **Age 9 through 14 years at initial vaccination and received 2 doses at least 5 months apart**: HPV vaccination complete, no additional dose needed
- If completed valid vaccination series with any HPV vaccine, no additional doses needed

Special situations

- **Immunocompromising conditions (including HIV infection) through age 26 years**: 3-dose series HPV vaccine at 0, 1–2, 6 months as above
- **Men who have sex with men and transgender persons through age 26 years**: 2- or 3-dose series HPV vaccine depending on age at initial vaccination as above
- **Pregnancy through age 26 years**: HPV vaccination not recommended until after pregnancy; no intervention needed if vaccinated while pregnant; pregnancy testing not needed before vaccination

Notes — Recommended Adult Immunization Schedule United States, 2019

Influenza vaccination

Routine vaccination

- **Persons age 6 months or older**: 1 dose IIV, RIV, or LAIV appropriate for age and health status annually
- For additional guidance, see www.cdc.gov/flu/professionals/index.htm

Special situations

- **Egg allergy, hives only**: 1 dose IIV, RIV, or LAIV appropriate for age and health status annually
- **Egg allergy more severe than hives** (e.g., angioedema, respiratory distress): 1 dose IIV, RIV, or LAIV appropriate for age and health status annually in medical setting under supervision of health care provider who can recognize and manage severe allergic conditions
- **Immunocompromising conditions (including HIV infection), anatomical or functional asplenia, pregnant women, close contacts and caregivers of severely immunocompromised persons in protected environment, use of influenza antiviral medications in previous 48 hours, with cerebrospinal fluid leak or cochlear implant**: 1 dose IIV or RIV annually (LAIV not recommended)
- **History of Guillain-Barré syndrome within 6 weeks of previous dose of influenza vaccine**: Generally should not be vaccinated

Measles, mumps, and rubella vaccination

Routine vaccination

- **No evidence of immunity to measles, mumps, or rubella**: 1 dose MMR
  - Evidence of immunity: Born before 1957 (except health care personnel [see below]), documentation of receipt of MMR, laboratory evidence of immunity or disease (diagnosis of disease without laboratory confirmation is not evidence of immunity)

Special situations

- **Pregnancy with no evidence of immunity to rubella**: MMR contraindicated during pregnancy; after pregnancy (before discharge from health care facility), 1 dose MMR
- **Non-pregnant women of childbearing age with no evidence of immunity to rubella**: 1 dose MMR
- **HIV infection with CD4 count ≥200 cells/μL for at least 6 months and no evidence of immunity to measles, mumps, or rubella**: 2-dose series MMR at least 4 weeks apart; MMR contraindicated in HIV infection with CD4 count <200 cells/μL
- **Severe immunocompromising conditions**: MMR contraindicated
- **Students in postsecondary educational institutions, international travelers, and household or close personal contacts of immunocompromised persons with no evidence of immunity to measles, mumps, or rubella**: 1 dose MMR if previously received 1 dose MMR, or 2-dose series MMR at least 4 weeks apart if previously did not receive any MMR
- **Health care personnel born in 1957 or later with no evidence of immunity to measles, mumps, or rubella**: 2-dose series MMR at least 4 weeks apart for measles or mumps, or at least 1 dose MMR for rubella; if born before 1957, consider 2-dose series MMR at least 4 weeks apart for measles or mumps, or 1 dose MMR for rubella

Meningococcal vaccination

Special situations for MenACWY

- **Anatomical or functional asplenia (including sickle cell disease), HIV infection, persistent complement component deficiency, eculizumab use**: 2-dose series MenACWY (Menactra, Menveo) at least 8 weeks apart and revaccinate every 5 years if risk remains
- **Travel in countries with hyperendemic or epidemic meningococcal disease, microbiologists routinely exposed to *Neisseria meningitidis***: 1 dose MenACWY and revaccinate every 5 years if risk remains
- **First-year college students who live in residential housing (if not previously vaccinated at age 16 years or older) and military recruits**: 1 dose MenACWY

Special situations for MenB

- **Anatomical or functional asplenia (including sickle cell disease), persistent complement component deficiency, eculizumab use, microbiologists routinely exposed to *Neisseria meningitidis***: 2-dose series MenB-4C (Bexsero) at least 1 month apart, or 3-dose series MenB-FHbp (Trumenba) at 0, 1–2, 6 months (if dose 2 was administered at least 6 months after dose 1, dose 3 not needed); MenB-4C and MenB-FHbp are not interchangeable (use same product for all doses in series)
- **Pregnancy**: Delay MenB until after pregnancy unless at increased risk and vaccination benefit outweighs potential risks
- **Healthy adolescents and young adults age 16 through 23 years (age 16 through 18 years preferred) not at increased risk for meningococcal disease**: Based on individual clinical decision, may receive 2-dose series MenB-4C at least 1 month apart, or 2-dose series MenB-FHbp at 0, 6 months (if dose 2 was administered less than 6 months after dose 1, administer dose 3 at least 4 months after dose 2); MenB-4C and MenB-FHbp are not interchangeable (use same product for all doses in series)

Notes Recommended Adult Immunization Schedule United States, 2019

Pneumococcal vaccination

Routine vaccination

- **Age 65 years or older** (immunocompetent): 1 dose PCV13 if previously did not receive PCV13, followed by 1 dose PPSV23 at least 1 year after PCV13 and at least 5 years after last dose PPSV23
  - Previously received PPSV23 but not PCV13 at age 65 years or older: 1 dose PCV13 at least 1 year after PPSV23
  - When both PCV13 and PPSV23 are indicated, administer PCV13 first (PCV13 and PPSV23 should not be administered during same visit)

Special situations

- **Age 19 through 64 years with chronic medical conditions (chronic heart [excluding hypertension], lung, or liver disease; diabetes), alcoholism, or cigarette smoking**: 1 dose PPSV23
- **Age 19 years or older with immunocompromising conditions (congenital or acquired immunodeficiency [including B- and T-lymphocyte deficiency, complement deficiencies, phagocytic disorders, HIV infection], chronic renal failure, nephrotic syndrome, leukemia, lymphoma, Hodgkin disease, generalized malignancy, iatrogenic immunosuppression [e.g., drug or radiation therapy], solid organ transplant, multiple myeloma) or anatomical or functional asplenia (including sickle cell disease and other hemoglobinopathies)**: 1 dose PCV13 followed by 1 dose PPSV23 at least 8 weeks later, then another dose PPSV23 at least 5 years after previous PPSV23; at age 65 years or older, administer 1 dose PPSV23 at least 5 years after most recent PPSV23 (note: only 1 dose PPSV23 recommended at age 65 years or older)
- **Age 19 years or older with cerebrospinal fluid leak or cochlear implant**: 1 dose PCV13 followed by 1 dose PPSV23 at least 8 weeks later; at age 65 years or older, administer another dose PPSV23 at least 5 years after PPSV23 (note: only 1 dose PPSV23 recommended at age 65 years or older)

Tetanus, diphtheria, and pertussis vaccination

Routine vaccination

- **Previously did not receive Tdap at or after age 11 years**: 1 dose Tdap, then Td booster every 10 years

Special situations

- **Previously did not receive primary vaccination series for tetanus, diphtheria, and pertussis**: 1 dose Tdap followed by 1 dose Td at least 4 weeks after Tdap, and another dose Td 6–12 months after last Td (Tdap can be substituted for any Td dose, but preferred as first dose); Td booster every 10 years thereafter
- **Pregnancy**: 1 dose Tdap during each pregnancy, preferably in early part of gestational weeks 27–36
- For information on use of Tdap or Td as tetanus prophylaxis in wound management, see www.cdc.gov/mmwr/volumes/67/rr/rr6702a1.htm

Varicella vaccination

Routine vaccination

- **No evidence of immunity to varicella**: 2-dose series VAR 4–8 weeks apart if previously did not receive varicella-containing vaccine (VAR or MMRV [measles-mumps-rubella-varicella vaccine] for children); if previously received 1 dose varicella-containing vaccine: 1 dose VAR at least 4 weeks after first dose
  - Evidence of immunity: U.S.-born before 1980 (except for pregnant women and health care personnel [see below]), documentation of 2 doses varicella-containing vaccine at least 4 weeks apart, diagnosis or verification of history of varicella or herpes zoster by a health care provider, laboratory evidence of immunity or disease

Special situations

- **Pregnancy with no evidence of immunity to varicella**: VAR contraindicated during pregnancy; after pregnancy (before discharge from health care facility), 1 dose VAR if previously received 1 dose varicella-containing vaccine, or dose 1 of 2-dose series VAR (dose 2: 4–8 weeks later) if previously did not receive any varicella-containing vaccine, regardless of whether U.S.-born before 1980
- **Health care personnel with no evidence of immunity to varicella**: 1 dose VAR if previously received 1 dose varicella-containing vaccine, or 2-dose series VAR 4–8 weeks apart if previously did not receive any varicella-containing vaccine, regardless of whether U.S.-born before 1980
- **HIV infection with CD4 count ≥200 cells/μL with no evidence of immunity**: Consider 2-dose series VAR 3 months apart based on individual clinical decision; VAR contraindicated in HIV infection with CD4 count <200 cells/μL
- **Severe immunocompromising conditions**: VAR contraindicated

Zoster vaccination

Routine vaccination

- **Age 50 years or older**: 2-dose series RZV 2–6 months apart (minimum interval: 4 weeks; repeat dose if administered too soon) regardless of previous herpes zoster or previously received ZVL (administer RZV at least 2 months after ZVL)
- **Age 60 years or older**: 2-dose series RZV 2–6 months apart (minimum interval: 4 weeks; repeat dose if administered too soon) or 1 dose ZVL if not previously vaccinated (if previously received ZVL, administer RZV at least 2 months after ZVL); RZV preferred over ZVL

Special situations

- **Pregnancy**: ZVL contraindicated; consider delaying RZV until after pregnancy if RZV is otherwise indicated
- **Severe immunocompromising conditions (including HIV infection with CD4 count <200 cells/μL)**: ZVL contraindicated; recommended use of RZV under review

Table 4a: **Vaccination coverage for selected diseases among children aged 19–35 months, by race, Hispanic origin, poverty level, and location of residence in metropolitan statistical area: United States, selected years 1998–2016**

Excel version (with more data years and standard errors when available): https://www.cdc.gov/nchs/hus/contents2017.htm#066.

[Data are based on telephone interviews of a sample of the civilian noninstitutionalized population, supplemented by a survey of interview participants' immunization providers]

		Race and Hispanic origin[1]						Poverty level[2]		Location of residence		
		Not Hispanic or Latino								Inside MSA[3]		
Vaccination and year	All	White only	Black or African American only	American Indian or Alaska Native only	Asian only[4]	Native Hawaiian or Other Pacific Islander only[4]	2 or more races	Hispanic or Latino	Below poverty level	At or above poverty level	Central city	Remaining area	Outside MSA[3]
Combined 7-vaccine series:[5]						Percent of children aged 19–35 months							
2009	44.3	45.2	39.6	*	38.6	*	40.7	45.9	41.3	45.7	44.8	44.6	42.4
2010	56.6	56.9	54.5	64.1	59.3	*	61.3	55.5	52.8	58.7	56.5	57.2	55.2
2012	68.4	69.3	64.8	*	71.6	*	71.5	67.8	63.4	71.6	67.6	69.4	68.0
2013	70.4	72.1	65.0	70.1	72.7	*	71.8	69.3	64.4	73.8	68.8	72.5	69.1
2014	71.6	72.6	65.4	*	69.5	*	68.5	74.3	65.7	75.4	70.8	72.7	71.2
2015	72.2	72.7	69.1	68.2	77.9	*	73.7	71.7	68.7	74.7	72.5	72.5	70.2
2016	70.7	72.2	64.1	68.5	72.3	*	71.5	71.0	66.0	72.5	71.3	71.1	67.0
DTP/DT/DTaP (4 doses or more):[6]													
1998	83.9	86.6	77.3	82.9	89.1	- - -	- - -	80.5	79.5	86.1	81.6	85.4	85.1
2000	81.7	84.4	76.1	77.8	84.5	*	81.5	78.6	76.2	83.5	79.9	82.8	82.9
2005	85.7	87.1	84.0	*	88.8	*	86.3	83.6	81.8	87.4	84.8	87.0	84.7
2009	83.9	85.8	78.6	82.1	86.6	93.1	81.8	82.9	80.1	85.7	83.8	84.2	84.2
2010	84.4	84.5	83.7	81.8	88.3	*	82.8	84.4	80.8	86.1	84.0	85.0	83.7
2012	82.5	83.6	79.6	88.2	88.1	*	85.6	80.8	78.5	85.0	82.4	83.4	80.5
2013	83.1	85.3	74.7	78.1	89.0	*	83.1	82.3	77.8	86.0	81.8	84.7	82.4
2014	84.2	85.5	79.1	*	87.4	*	79.6	85.4	79.1	87.4	83.6	85.3	83.1
2015	84.6	85.2	82.0	79.6	90.0	*	82.5	84.5	80.2	87.1	85.4	84.3	82.7
2016	83.4	84.8	76.8	83.5	86.4	83.2	83.6	83.3	79.2	85.1	83.3	84.8	78.8
Polio (3 doses or more):													
1998	90.8	92.2	87.8	85.1	93.4	- - -	- - -	88.9	89.9	91.7	89.3	91.3	92.9
2000	89.5	90.6	86.6	90.8	92.7	91.2	91.2	87.9	86.9	89.9	88.1	90.1	91.1
2005	91.7	91.4	91.0	*	92.9	*	93.8	92.3	89.7	92.4	90.6	92.6	92.2
2009	92.8	93.3	90.9	92.2	94.0	97.3	92.8	92.5	92.0	93.3	93.5	92.1	92.1
2010	93.3	93.2	94.0	94.6	92.8	95.1	90.2	93.8	92.4	93.6	92.7	94.1	93.1
2012	92.8	93.0	92.9	95.2	92.3	*	93.3	92.5	91.8	93.4	92.6	92.9	92.8
2013	92.7	93.7	91.2	92.2	95.5	*	90.8	91.6	89.2	94.4	91.9	93.2	93.4
2014	93.3	93.3	92.0	93.8	93.2	93.8	94.0	93.8	92.0	94.5	92.7	94.2	92.7
2015	93.7	93.1	93.3	91.8	96.9	92.8	92.4	94.5	91.8	94.6	93.9	94.0	91.7
2016	91.9	92.5	90.3	92.4	94.7	91.3	89.4	91.7	90.6	92.5	92.0	92.2	90.8

Table 4b: **Vaccination coverage for selected diseases among children aged 19–35 months, by race, Hispanic origin, poverty level, and location of residence in metropolitan statistical area: United States, selected years 1998–2016**

Excel version (with more data years and standard errors when available): https://www.cdc.gov/nchs/hus/contents2017.htm#066.

[Data are based on telephone interviews of a sample of the civilian noninstitutionalized population, supplemented by a survey of interview participants' immunization providers]

		Race and Hispanic origin[1]							Poverty level[2]		Location of residence		
		Not Hispanic or Latino									Inside MSA[3]		
Vaccination and year	All	White only	Black or African American only	American Indian or Alaska Native only	Asian only[4]	Native Hawaiian or Other Pacific Islander only[4]	2 or more races	Hispanic or Latino	Below poverty level	At or above poverty level	Central city	Remaining area	Outside MSA[3]
Measles, mumps, rubella:[7]						Percent of children aged 19–35 months							
1998	92.0	93.1	88.8	91.4	92.2	- - -	- - -	91.0	90.1	93.1	91.3	92.4	92.4
2000	90.5	91.6	87.7	89.4	89.3	94.5	88.1	90.0	88.9	90.9	89.7	91.0	90.8
2005	91.5	91.4	91.9	89.7	91.9	90.3	93.7	91.1	89.3	92.1	91.6	91.8	90.4
2009	90.0	90.8	88.2	94.9	90.7	96.9	88.5	89.3	88.8	90.6	91.1	88.6	88.6
2010	91.5	90.6	92.1	93.4	91.7	96.9	89.7	92.9	91.3	91.4	92.4	90.5	91.4
2012	90.8	90.9	90.9	92.0	89.8	*	92.3	90.7	89.9	91.4	90.1	91.0	92.4
2013	91.9	91.5	90.9	96.3	96.7	90.4	91.5	92.1	90.5	92.5	91.5	92.4	91.3
2014	91.5	91.2	90.3	96.5	95.7	95.7	90.5	91.9	89.5	92.8	91.9	91.2	91.2
2015	91.9	91.8	90.7	88.5	92.5	92.0	93.0	92.3	90.3	92.9	92.4	91.7	90.7
2016	91.1	91.6	89.4	91.3	93.6	86.1	91.0	90.6	89.0	92.1	91.3	91.7	88.5
Hib (full series):[8]													
2009	54.8	55.3	51.2	*	54.6	*	53.7	55.4	51.4	56.5	55.5	54.9	53.0
2010	66.8	67.5	65.4	77.1	69.5	*	70.1	64.8	61.3	69.7	66.5	68.4	63.4
2012	80.9	82.2	77.5	84.7	86.1	*	82.5	79.5	76.4	84.0	80.5	81.8	79.9
2013	82.0	84.2	74.9	82.9	82.0	*	84.9	80.9	75.8	85.3	80.6	84.3	79.7
2014	82.0	83.8	75.2	83.8	83.1	*	78.7	82.8	76.3	85.5	81.4	82.7	81.6
2015	82.7	83.0	78.9	81.4	87.0	*	82.4	83.0	78.1	85.5	82.3	83.6	80.9
2016	81.8	83.0	75.6	82.9	83.5	*	83.0	82.1	77.4	83.6	81.5	83.2	78.2
Hepatitis A (2 doses or more):													
2009	46.6	46.2	41.3	33.2	50.9	*	47.8	49.3	47.3	46.2	48.2	46.9	42.0
2010	49.7	45.8	48.6	*	50.8	*	49.8	57.0	51.0	49.1	52.4	48.8	45.1
2012	53.0	52.6	52.0	*	57.5	*	49.4	54.4	49.4	55.4	54.7	53.0	48.2
2013	54.7	53.4	49.1	*	67.3	*	57.8	56.6	53.5	56.1	55.5	55.2	50.1
2014	57.5	55.4	56.7	*	67.7	*	53.7	61.6	54.0	59.2	58.9	58.1	51.2
2015	59.6	58.7	59.3	61.3	67.8	*	54.1	60.9	56.0	61.7	60.5	59.6	55.7
2016	60.6	60.0	53.9	69.8	69.7	*	57.4	63.6	56.9	61.9	62.1	60.5	55.6
Hepatitis B (3 doses or more):													
1998	87.0	88.3	83.7	81.6	89.0	- - -	- - -	85.7	85.3	87.7	85.3	88.3	87.4
2000	90.3	91.4	88.8	91.9	89.5	93.1	92.6	88.2	87.3	91.4	89.4	90.3	92.3
2005	92.9	93.1	92.7	90.1	92.7	*	94.4	92.7	91.4	93.5	91.8	93.9	93.4
2009	92.4	92.3	91.6	92.5	93.1	96.2	93.3	92.6	92.3	92.7	92.8	91.8	91.8
2010	91.8	91.4	92.1	97.2	91.7	96.7	89.9	92.5	91.5	92.0	91.2	92.0	92.7
2012	89.7	89.3	89.7	94.0	93.2	*	92.2	89.4	89.4	89.8	89.5	89.6	90.7
2013	90.8	91.0	91.1	96.1	92.0	94.9	90.7	89.7	88.3	92.0	89.6	91.8	91.4
2014	91.6	90.7	92.3	98.5	92.9	95.2	92.9	91.9	91.3	92.0	90.5	92.5	91.9
2015	92.6	92.0	93.3	92.4	95.5	94.1	91.4	93.2	92.5	92.7	92.9	92.5	92.1
2016	90.5	91.3	90.0	91.0	93.8	86.0	88.8	89.1	90.5	90.5	90.9	89.9	91.2

Table 4c: **Vaccination coverage for selected diseases among children aged 19–35 months, by race, Hispanic origin, poverty level, and location of residence in metropolitan statistical area: United States, selected years 1998–2016**

Excel version (with more data years and standard errors when available): https://www.cdc.gov/nchs/hus/contents2017.htm#066.

[Data are based on telephone interviews of a sample of the civilian noninstitutionalized population, supplemented by a survey of interview participants' immunization providers]

		Race and Hispanic origin[1]							Poverty level[2]		Location of residence		
		Not Hispanic or Latino									Inside MSA[3]		
Vaccination and year	All	White only	Black or African American only	American Indian or Alaska Native only	Asian only[4]	Native Hawaiian or Other Pacific Islander only[4]	2 or more races	Hispanic or Latino	Below poverty level	At or above poverty level	Central city	Remaining area	Outside MSA[3]
Varicella:[7]						Percent of children aged 19–35 months							
1998	43.2	41.9	42.4	28.0	52.6	- - -	- - -	46.9	40.5	44.1	45.1	45.2	34.3
2000	67.8	66.3	67.6	65.8	76.3	*	69.7	70.2	63.5	69.2	69.0	69.8	60.2
2005	87.9	86.1	90.6	82.2	91.9	*	90.1	89.2	87.3	87.7	88.4	88.2	85.7
2009	89.6	89.2	88.2	89.2	89.5	97.5	90.6	90.7	89.0	90.2	90.6	88.5	88.5
2010	90.4	88.9	91.5	95.7	92.5	92.7	88.9	92.3	89.6	90.6	90.8	90.1	90.0
2012	90.2	89.8	90.4	92.5	91.9	*	90.9	90.9	89.7	90.6	90.1	90.0	91.3
2013	91.2	90.0	92.1	95.4	96.0	88.7	91.0	92.0	90.3	91.6	91.1	91.6	90.3
2014	91.0	90.3	90.1	95.7	95.3	94.9	90.0	92.1	89.9	91.9	91.4	91.1	89.8
2015	91.8	91.2	91.8	87.8	93.4	91.8	92.1	92.7	90.6	92.5	92.5	91.5	89.9
2016	90.6	90.8	89.9	90.9	94.2	86.7	89.3	90.2	89.3	91.2	91.2	90.7	88.0
PCV (4 doses or more):[9]													
2005	53.7	57.3	46.2	*	56.2	*	54.2	50.5	44.6	57.1	51.7	57.7	48.4
2009	80.4	83.4	73.2	76.2	72.5	*	73.1	80.6	74.8	83.2	79.7	81.8	81.8
2010	83.3	84.2	79.7	85.3	78.9	*	83.0	83.9	78.7	85.6	82.6	84.3	82.6
2012	81.9	83.5	77.1	*	80.7	*	84.1	82.1	76.7	85.3	80.4	84.0	80.8
2013	82.0	84.1	76.1	79.0	85.6	*	83.0	80.4	74.5	86.1	80.7	84.1	79.9
2014	82.9	84.5	78.0	*	80.9	93.1	82.1	83.2	76.9	86.9	81.4	84.5	82.9
2015	84.1	85.0	81.4	77.1	85.0	*	83.7	84.0	78.9	87.2	83.9	85.5	80.4
2016	81.8	84.1	74.5	80.1	81.0	82.9	82.9	81.4	76.8	84.2	82.5	82.1	78.4
Rotavirus vaccine:[10]													
2009	43.9	46.4	38.0	*	41.7	*	38.4	43.7	37.7	47.1	44.6	46.6	35.6
2010	59.2	60.2	52.7	*	62.6	*	57.7	60.5	51.5	62.9	59.2	62.2	51.6
2012	68.6	70.5	60.4	*	69.9	*	69.3	70.0	63.0	72.5	68.8	70.5	62.5
2013	72.6	74.8	62.1	*	74.9	*	72.8	73.7	64.3	76.9	72.4	74.7	66.7
2014	71.7	74.8	61.6	*	72.4	*	73.9	71.3	62.8	76.9	71.2	73.2	68.4
2015	73.2	74.6	69.7	*	75.6	*	70.6	72.9	66.8	76.8	72.7	75.1	68.6
2016	74.1	77.3	67.2	*	71.8	*	73.4	73.0	65.5	78.2	74.9	74.2	70.3

Table 4d. Vaccination coverage for selected diseases among children aged 19–35 months, by race, Hispanic origin, poverty level, and location of residence in metropolitan statistical area: United States, selected years 1998–2016

Excel version (with more data years and standard errors when available): https://www.cdc.gov/nchs/hus/contents2017.htm#066.

[Data are based on telephone interviews of a sample of the civilian noninstitutionalized population, supplemented by a survey of interview participants' immunization providers]

	Not Hispanic or Latino					
	White only		Black or African American only		Hispanic or Latino	
Vaccination and year	Below poverty level[2]	At or above poverty level[2]	Below poverty level[2]	At or above poverty level[2]	Below poverty level[2]	At or above poverty level[2]
Combined 7-vaccine series:[5]	Percent of children aged 19–35 months					
2009	43.2	45.6	37.8	43.5	43.5	48.5
2010	48.7	59.0	53.4	56.3	55.0	55.2
2012	58.2	72.1	62.7	68.5	68.1	68.3
2013	61.3	74.9	60.4	69.1	68.6	70.2
2014	61.2	75.4	61.5	71.0	71.8	79.4
2015	64.1	75.4	65.8	73.2	72.9	70.1
2016	61.2	74.6	65.0	64.4	70.8	68.9

* Estimates are considered unreliable. For data prior to 2007 (shown in spreadsheet version), percentages are not shown if the unweighted sample size for the numerator was less than 30, or the confidence interval half-width divided by the estimate was greater than 50%, or the confidence interval half-width was greater than 10. Starting with 2007 data, percentages are not shown if the unweighted sample size for the denominator was less than 30, or the confidence interval half-width divided by the estimate was greater than 58.8%, or the confidence interval half-width was greater than 10.

- - - Data not available.

[1]Persons of Hispanic origin may be of any race. Starting with 2000 data, estimates were tabulated using the 1997 *Revisions to the Standards for the Classification of Federal Data on Race and Ethnicity.* Estimates for earlier years were tabulated using the 1977 Standards on Race and Ethnicity. See Appendix II, Hispanic origin; Race.

[2]Poverty level is based on family income and family size using U.S. Census Bureau poverty thresholds. In 2016, 3.7% of the 14,988 children with provider-reported vaccination history data, 6.3% of Hispanic, 2.4% of non-Hispanic white, and 6.5% of non-Hispanic black children, were missing information about poverty level and were omitted from the estimates of vaccination coverage by poverty level (unweighted percentages). See Appendix II, Family income; Poverty. See Appendix I, National Immunization Survey (NIS).

[3]MSA is metropolitan statistical area. See Appendix II, Metropolitan statistical area (MSA).

[4]Prior to data year 2000, the category Asian included Native Hawaiian or Other Pacific Islander.

[5]The combined 7-vaccine series consists of 4 or more doses of either the diphtheria, tetanus toxoids, and pertussis vaccine (DTP), the diphtheria and tetanus toxoids vaccine (DT), and the diphtheria, tetanus toxoids, and acellular pertussis vaccine (DTaP); 3 or more doses of any poliovirus vaccine; 1 or more doses of a measles-containing vaccine (MCV); 3 or more doses or 4 or more doses of *Haemophilus influenzae* type b vaccine (Hib) depending on Hib vaccine product type (full series Hib); 3 or more doses of hepatitis B vaccine; 1 or more doses of varicella vaccine; and 4 or more doses of pneumococcal conjugate vaccine (PCV). The vaccine shortage that ended in September 2004 might have reduced coverage with the fourth dose of PCV among children in the 2007 National Immunization Survey (NIS)–Child. See footnote 8 for additional information on (Hib) vaccination.

[6]Includes the diphtheria, tetanus toxoids, and pertussis vaccine (DTP), the diphtheria and tetanus toxoids vaccine (DT), and the diphtheria, tetanus toxoids, and acellular pertussis vaccine (DTaP).

[7]Includes children who may have been vaccinated with at least 1 dose of measles, mumps, rubella, and varicella vaccine.

[8]*Haemophilus influenzae* type b vaccine (Hib) full series includes primary series and the booster dose. Before January 2009, NIS did not distinguish between Hib vaccine product types; therefore, children who received 3 doses of a vaccine product that requires 4 doses were misclassified as fully vaccinated. In addition, there was a Hib vaccine shortage during December 2007 –September 2009. For more information, see: CDC. Changes in measurement of *Haemophilus influenzae* serotype b (Hib) vaccination coverage—National Immunization Survey, United States, 2009. MMWR Morb Mortal Wkly Rep 59(33):1069–72. Available from: https://www.cdc.gov/mmwr/preview/mmwrhtml/mm5933a3.htm?s_cid=mm5933a3_e%0d%0a.

[9]PCV is pneumococcal conjugate vaccine. Recommended in 2000. Data collection for PCV began in July 2001. Data for 4 doses of PCV are not available prior to 2005.

[10]Rotavirus vaccine includes 2 or more or 3 or more doses, depending on the product type received. Recommended in 2006. Data collection for rotavirus began in 2009.

NOTES: Vaccine coverage is based on provider-reported vaccination data. Complex statistical methods were used to adjust vaccination estimates to account for refusals, households without telephones, and children whose vaccination histories could not be verified through their providers. Starting in 2011, the NIS sampling frame was expanded from a single-landline frame to dual-landline and cellular telephone sampling frames. See Appendix I, National Immunization Survey (NIS). See Appendix II, Vaccination. Additional information on childhood immunizations is available from: https://www.cdc.gov/vaccines/schedules/index.html. Data for additional years are available. See the Excel spreadsheet on the *Health, United States* website at: https://www.cdc.gov/nchs/hus.htm.

SOURCE: NCHS and National Center for Immunization and Respiratory Diseases (NCIRD) (data for 1998–2014); NCIRD (data for 2015 onwards), National Immunization Survey–Child. Available from: https://www.cdc.gov/vaccines/imz-managers/nis/index.html. See Appendix I, National Immunization Survey (NIS).

Table 5: Health Provider-Based Interventions to Improve Vaccination Compliance[3,4,6,9,12,14]

Provide Parent and Patient Counseling
• Be informed about vaccinations. • Make strong recommendations. • Provide patients with educational materials. • Use proven communication strategies. • Dispel myths about side effects. • Inform parents about research. • Give parents time to discuss concerns. • Describe infections that vaccines prevent. • Describe potential health and financial consequences of vaccine noncompliance. • Provide a vaccination record with past and future vaccination visits. • Provide patient reminders. • Ask vaccine-hesitant parents to sign an exemption form. • Inform parents that a missed dose will not require vaccine series to be restarted.
Maximize Opportunities for Vaccination
• Administer vaccinations during sick or follow-up visits (postsurgical, posthospitalization). • Issue a standing order to allow nurses to administer patient vaccinations.
Offer Combination Vaccines
• Simplifies vaccination regimen. • Minimizes the number of injections. • Reduces need for return vaccination visits. • Improves patient adherence.
Improve Accessibility to Vaccinations
• Allow same-day appointments or walk-in visits. • Make sure the office staff is friendly and supportive. • Provide convenient office hours. • Limit patient wait time.
Use Electronic Medical Records
• Utilize consolidated electronic immunization records. • Set electronic alerts for needed vaccinations. • Follow up on electronic medical record alerts by contacting patient.

Table 6: Community- and Government-Based Interventions to Improve Vaccination Compliance[3,4,7,9]

Public Education
• Distribute educational materials that incorporate community input. • Conduct public messaging campaigns. • Use electronic communications to distribute health and safety information.
Public Reminder and Recall Strategies
• Conduct centralized reminder and recall strategies through public agencies or payers. • Use electronic communications, such as social media and text messaging, for reminder and recall programs.
Free Vaccines and Other Financial Incentives
• Provide free vaccines to uninsured patients. • Issue financial incentives, such as gift certificates.
Alternative Public and Private Venues for Vaccination
• Day care facilities • Drop-in service at walk-in clinics • Pharmacies • Women, Infants, and Children (WIC) program offices • Emergency departments • Inpatient settings • Home visits